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AN EVALUATION OF COMPUTATIONAL METHODS AND
DATA SOURCES FOR THE COMPUTER DESIGN OF
ABSORBERS AND REBOILED ABSORBERS

BY

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING

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ABSTRACT

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Computational rigorous methods for the solution of absorbers and reboiled absorbers have been developed. The methods, one a "bubble point" method and the other a "sum rates" method, are compared for relative merit.

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "An Evaluation of Computational Methods and Data Sources for the Computer Design of Absorbers and Reboiled Absorbers" submitted by Dennis Walter Burningham in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering. The sum rates method did not reach

a solution for the reboiled absorber problem.

ABSTRACT

Computer programs employing two rigorous methods for the solution of absorbers and reboiled absorbers have been developed. The methods, one a "bubble point" method and the other a "sum rates" method, are compared for relative merit. Two sources of equilibrium and enthalpy data have been tried with each method. These are the Chao-Seader correlation and the combination of NGAA polynomial K data and the Yen and Alexander enthalpy data correlation.

The sum rates method was found to calculate an absorber solution up to six times more quickly than a bubble point method using the same data. The sum rates method did not reach a solution for the reboiled absorber problems attempted. Convergent solutions for the absorber and reboiled absorber were obtained using the bubble point procedure.

Significant differences in results were obtained with different sources of data. The NGAA and Yen and Alexander data required a special method of determining stream enthalpies and gave results at some variance to those from the other data. Chao-Seader data provided results which checked reasonably with the one set of operating data available. The programs were up to twelve times slower in reaching a solution when using Chao-Seader data than when using NGAA and Yen and Alexander data in some of the problems attempted.

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1. INTRODUCTION

Absorbers and reboiled absorbers are of great importance to the natural gas industry for the recovery of propane, butanes and heavier components from the raw gas. Absorbers, by the countercurrent contact of a lean oil with the raw or 'wet' gas, cause the heavier components in the gas to be absorbed into the oil. However, if special precautions are not taken, an undesirable amount of the lighter components, such as methane and ethane, may be absorbed and the percentage absorption of the propane and heavier components may not be as high as desired.

Gilmore and Bauer(1) state that there are four changes that can be made to an existing absorber to improve the percentage recovery of propane. These are:

1. increase the pressure,
2. increase the molal ratio of absorption oil to gas,
3. lower the temperature of absorption, or
4. increase the number of theoretical trays.

All of these may be either uneconomical or impossible because of the existing conditions.

An economical change may be the addition of a stripping section with a reboiler below the feed plate, thus producing a fractionating absorber. If this is not practicable, the rich oil from the absorber may be fed to a reboiled absorber where the split between the undesirable ethane and methane and the desired heavier components can be accomplished.

Various modes of employing the reboiled absorber to increase propane recovery while restricting the amount of ethane and methane absorbed have been put forward(1,2,3,4,5). The advantages of using a reboiled absorber as opposed to increasing the lean oil rate in an existing absorber are described by Kneil(5).

The rigorous design of separation devices such as absorbers and reboiled absorbers is of obvious worth to the design engineer. Hand calculations of multicomponent separation problems of this type are expensive in engineer-hours. They have the limitations of giving only approximate solutions and of being unable to properly consider side stream take-offs and interheaters/coolers. Furthermore, the time taken to calculate a single case precludes the trying of different specifications in an effort to establish the optimum design.

Several methods of rigorous solution for use with the modern high-speed digital computer have been put forward(6,7,8,9,10,11,12). All are based on an iterative procedure where the trial and error calculation is carried toward a solution by the use of successively better values for the column variables. These improved values are available as a result of the calculations of the previous iteration, except in the case of the first iteration where assumed values are used to initiate the calculations.

The various methods available may be classified into two groups.

1. 'Bubble Point' - Those methods which use the plate compositions to determine the new plate temperatures by a bubble point calculation, and then use enthalpy balances to determine the new vapor and liquid flow profiles.
2. 'Sum Rates' - Those methods which use a summation of the component molal flow rates from each plate to give the new flow profiles and then use enthalpy balances to find the new plate temperatures.

In both of these groups, the equilibrium and enthalpy data used has been provided primarily in the form of analytical expressions determined from curve fits of available data. Because the fitting of data is time consuming and must be carried out each time a change in conditions is made, a great deal of interest has been taken in general correlations which can provide data over a wide range of conditions. The general correlations which have been developed are based on thermodynamic principles(13,14,15,16). Besides eliminating the necessity of curve fitting experimental data, they also provide a consistency between problems and avoid the human errors possible in the transcribing of data in the curve fitting procedures. A further advantage is that a general correlation can provide consistent data for components such as H_2S , CO_2 and heavy fractions for which there are limited experimental data.

Of these general correlations, the Chao-Seader correlation is of particular interest. It has been applied in the solution of distillation problems by Cavett(6) and

Tatuch(7). Erbar(8) has employed this correlation in a composite program which carries out flash calculations for various specifications as well as bubble and dewpoint determinations.

Only limited information is available on the use of the various calculational procedures for the rigorous design of absorbers and reboiled absorbers. No information has been published, to date, about the use of the generalized correlations in the design of these devices.

The objectives of this work are:

1. To prepare computer programs for the rigorous design of absorbers and reboiled absorbers based on the two general calculational methods and to investigate the relative merit of the two methods.
2. To incorporate the following sources of equilibrium and enthalpy data into the calculational procedure and evaluate their use.
 - a. Chao-Seader correlation
 - b. NGAA equilibrium ratio data and Yen and Alexander enthalpy data correlation

All programs are written in Fortran IV and were used on the IBM 7040 computer of the University of Alberta Computing Science Department.

2. LITERATURE REVIEW

2.1 Computational Procedures

Several rigorous design methods for absorbers and re-boiled absorbers for use with digital computers have been published in recent years. Hogsett et al(9) described a short-cut computer program for designing absorbers by the modified Edminster method(10) which uses effective absorption and stripping factors. The specifications required are the number of theoretical trays; lean oil and wet gas composition and temperature; equilibrium and enthalpy data for each component; and the recovery of the key component required. This program has the advantage of giving fairly accurate design information in less computer time than more rigorous methods and can thus be used to advantage in preliminary economic studies and as a starting point for more rigorous design methods.

A sum rates method of solving absorber problems was presented by McNeese(11) in which the plate to plate material balance equations of the column for a particular temperature profile are solved to give flow rates and compositions for each tray. This procedure is carried out in a trial and error fashion until the unique value for the temperature profile is obtained. Using these new flow rates and compositions, the necessary temperatures for thermal equilibrium on each tray of the absorber are calculated in a trial and error procedure using enthalpy balances. If the new temperatures vary from

the former temperatures by more than a specified tolerance, the material balance calculation is repeated with the new temperature profile. Special convergence techniques are used to force convergence. The disadvantages of this method are the need for an iterative solution of the flow profiles for each temperature profile, the non-rigorous trial and error method of solving for the new temperature profile, and the need for convergence forcing techniques. The specifications necessary are: the number of theoretical trays; the lean oil and wet gas compositions, temperatures and rates; the number, location and duty of interheaters/coolers; equilibrium and enthalpy data; and the convergence tolerances for the heat and material balances. An example problem involving a feed gas of twelve components (including N_2 , CO_2 , H_2S and hydrocarbons from methane through heptane), a pre-saturated lean oil (API 78.3), a column of six theoretical trays operating at 1200 psia with an intercooler, is presented. The source of data is not stated.

Sujata(12) suggests another sum rates method of solution for absorbers and strippers which can theoretically be extended to accommodate feeds and interheaters/coolers on any or every stage. This method requires the specification of: the number of theoretical trays; the lean oil and wet gas compositions, temperatures and rates; the number location and duties of interheaters/coolers; equilibrium and enthalpy data; and the required absorption of the key component. Once a

solution is reached where the temperature profile no longer changes appreciably between iterations, the calculated key component absorption is compared to that specified and the lean oil rate adjusted so as to correct the difference. The material and heat balance solution is carried out with these successively better estimates of the lean oil rate until the calculated key component absorption agrees within a specified tolerance with the specified key component absorption. This method can be extended to rectified absorbers and fractionators. Sujata makes no comparison of results to operating data and does not discuss the data used in the solution of a two feed absorber example. His method works well for columns having a temperature differential over the entire absorber of less than 100° and may not converge for reboiled absorbers at all.

Friday(13) describes a method similar to that of Sujata. His program is capable of giving design information for distillation and extraction columns as well as absorbers. In this paper the various methods of solution used throughout the years are classified according to the order in which the material and enthalpy balances are solved. The various decisions that must be made in the formulation of a solution method for a design problem are set out and discussed. A matrix method is used in the solution of both the material and energy balance equations to avoid truncation error buildup. Various example problems are solved and compared to results published by other workers in this field. Friday states that the poly-

nomial data which he uses are accurate enough to show that his method works. No discussion of the effect of data on results is presented. Friday does not present a method for solving the reboiled absorber.

A series of articles dealing with the use of the Theile-Geddes bubble point method began in the Petroleum Refiner in the issue of June 1959. In the series, the article by Hardy et al(14) explains the use of this method for the solution of absorbers and describes a method of avoiding the round-off error associated with multifeed columns. Three types of specification are presented for the absorber. In addition, the "Q" method of arranging enthalpy balances so that interheaters/coolers can be introduced to maintain specified flow rates is explained. The constant composition method of calculating stream enthalpy is introduced to avoid round-off errors associated with conventional enthalpy balances. Several example problems are presented covering both adiabatic and non-adiabatic operation.

Hardy et al(15) apply the same basic method to the case of reboiled absorbers with bottom side streams. Example problems are presented to indicate the capabilities of the program.

2.2 Equilibrium Data

Several correlations providing equilibrium data for use in digital computer programs have been presented in recent years(16,17,18). The equilibrium ratios of the Natural Gas

Association of America, which account for the effect of composition on the equilibrium ratio by the convergence pressure concept of Hadden, are presented in chart form as a function of temperature and pressure. Analytical expressions representing these charts have been prepared by NGAA to give the equilibrium ratios of the hydrocarbons methane through decane. If non-hydrocarbons and hydrocarbons other than the twelve treated by the NGAA expressions are to be used, extensive curve fitting must be carried out.

The Chao-Seader correlation(17) is a general correlation for equilibrium ratios based on fundamental thermodynamic relationships. In addition to hydrocarbons of various molecular types (paraffins, olefins, aromatics and naphthalenes), it can provide equilibrium data for CO_2 , H_2S , N_2 , H_2 , O_2 , CO and heavier hypothetical hydrocarbon fractions over a wide range of pressure and temperature. It has the advantages of providing a consistent source of equilibrium data from problem to problem and can provide a correspondingly consistent source of enthalpy data. Other similar equilibrium ratio correlations lack this final advantage. The major disadvantage of general correlations of the Chao-Seader type is the increased computer time required to generate the data desired.

2.3 Enthalpy Data

The enthalpy data used in the solution of separation problems by digital computer must ideally be available in such

a form that the individual values of enthalpy can be calculated from a general expression rather than in a form requiring the interpolation of a table of discrete values. Of the general correlations developed in recent years(19,20,21), the two of interest are the Yen and Alexander(20) and the Chao-Seader as extended by Edmister et al(21).

Yen and Alexander, using improved Lydersen-Greenkorn-Hougen charts have correlated the enthalpy departure of a component from ideal gas behavior according to a modified theory of corresponding states. Equations are presented for four regions: the superheated vapor; the saturated vapor; the saturated liquid; and the subcooled liquid, at selected values of the critical compressibility factor, whereby the enthalpy departure can be calculated with a knowledge of the reduced temperature and reduced pressure. The range of applicability of this correlation is varied according to the region being worked in. Enthalpies of hydrocarbon mixtures are determined using pseudo-critical properties for the mixture as determined using Kay's rule.

The Chao-Seader correlation, as extended to provide enthalpy data by Edmister et al(21), calculates the enthalpy of pure components, and mixtures of components, according to fundamental thermodynamic relationships in a manner which will be explained in Section 4.2-2. The data thus provided are consistent with the equilibrium data calculated by the correlation.

2.4 Operating Data

Operating data for existing columns are scarce in the literature. Jackson et al(22) present a complete set of operating conditions for an absorber with and without an intercooler in both winter and summer operation. The feed consists of H_2S and hydrocarbons from methane through pentane with a lean oil of 35° API gravity. The column operates at a pressure of approximately 70 psia and over a temperature range of 50 to $80^\circ F$. The absorber is also solved by a short cut design procedure and the results compared with those observed from actual operation.

Goldblatt et al(3) provide operating data for a reboiled absorber in a gasoline plant which is used to de-ethanize a rich oil from a previous absorber. The equipment operates at approximately 150 psia over a temperature range of 85 to $250^\circ F$. Compositions and temperatures of the feed and product streams are presented for two methods of operation using preheaters and reboilers. Unfortunately, the number of theoretical plates is not stated. Kneil(5) and Gilmore and Bauer(1) provide similar operational data for two other reboiled absorbers. Kneil fails to state the number of theoretical stages in the equipment while Gilmore and Bauer have described a very particular reboiled absorber with a complicated intercooler system which cannot be simulated with accuracy without more information.

3. COMPUTATIONAL PROCEDURE

3.1 General

Friday and Smith(23) give a comprehensive analysis of the various methods available for the solution of separation problems. Briefly, in rigorous separation calculation there are four sets of equations which must be satisfied. These are:

The material balance equations (A)

$$l_{in} + v_{in} - l_{in-1} - v_{in+1} - f_{in} = 0 \quad (3-1)$$

The equilibrium relationships (B)

$$y_{in} = K_{in} x_{in} \quad (3-2)$$

The summation relationships (C)

$$\begin{aligned} \sum_i x_{in} - 1.0 &= 0 \quad \text{and} \\ \sum_i y_{in} - 1.0 &= 0 \end{aligned} \quad (3-3)$$

The energy balance equations (D)

$$L_n h_n + V_n H_n - L_{n-1} h_{n-1} - V_{n+1} H_{n+1} - F_n H_{F_n} - Q_n = 0 \quad (3-4)$$

It is in the method of satisfying these equations that the various methods of rigorous solution differ. Certain decisions must be made regarding these equations before a method of solution can be formulated.

First, in all the commonly used solutions, the four equations are dealt with individually throughout the column by type, instead of all four being grouped together in a stage

by stage procedure. This is necessary because of the round off errors associated with the stage to stage method.

Secondly, the order in which the equations will be used must be determined. Equations (A,B) are employed together and are satisfied before (C,D) in all cases. However, the order in which equations (C) and (D) are solved depends on the next decision.

Thirdly, the decision as to which equation will be used to solve for which column variable must be made. The variables which must be determined for the column are the plate compositions, the flow profiles and the temperature profile. The plate compositions are determined by the equations (A,B). A choice must be made between two alternatives for the determination of the flow and temperature profiles. These are:

1. The Bubble Point Method, where equation (C) is used to solve for the temperature profile by a bubble point calculation and equation (D) is used to solve for the new flow rates.
2. The Sum Rates Method, where equation (C) is used to solve for the flow rates by a summation of the component molal flow rates on each plate and equation (D) is used to calculate the new temperature profile by means of enthalpy balances.

Fourth, a decision must be made as to the method by which the equations (A,B) are solved. Because of the round-off error associated with some methods, the way in which (A,B)

are solved must be selected with some care.

Fifth, a decision as to how to calculate the new temperature profile from the equation decided on in the third decision is required. If the Bubble Point procedure is to be employed, any one of the several methods of determining a bubble point may be used. In the case of the Sum Rates calculation, a matrix method of solution such as described by Sujata(12) or Friday(13) may be used.

The sixth decision, as to how to calculate the new flow profiles from the equation decided on in the third decision, is dependent on the method selected of course. In the case of the Sum Rates method

$$V_n = \sum_i v_{in} \quad (3-5)$$

$$L_n = \sum_i l_{in} \quad (3-6)$$

However, in the case of the Bubble Point procedure, the new flow profiles can be determined from the enthalpy balances of equation (D) using either 'conventional' or 'constant composition' stream enthalpies. In addition, if there are any maximum/minimum restrictions on the vapor or liquid flows, the "Q" method of enthalpy balances, as described by Holland(24), can be used to establish the duty of any interheaters/coolers required.

In the case of the two types of solution used in this work, the Theile-Geddes method, as described by Hardy et al(14,15)

is used for the solution of equations (A,B) for both. The order and method of solution of equations (C) and (D) differs, however. The first method, which will be called the Theile-Geddes method, uses the Bubble Point procedure while the second, which will be called the Sum Rates method, uses the Sum Rates procedure.

3.2 Degrees of Freedom

In the solution of equilibrium stage problems by use of the digital computer, it is necessary to determine the number of variables which must be specified to give a unique solution. Smith(26) has discussed fully a method of accomplishing this which is attributed to Kwauk. In applying the "design variables" analysis, Smith's nomenclature will be used, where C is the number of components and N is the number of stages.

3.2.1 Absorber

Following the procedure described by Smith, the absorber in Figure 1 can be shown to have $2C + 2N + 5$ degrees of freedom. These will be taken up as follows:

	<u>Degrees of Freedom</u>
Heat leak on each stage	N
Pressure on each stage	N
Stream L_0 - Rate, temperature, pressure and composition	C + 2
Stream F - Rate, pressure and composition	C + 1
Stream V(1) - Rate	1
Number of stages	1
Total	<hr/> 2N + 2C + 5

ABSORBER

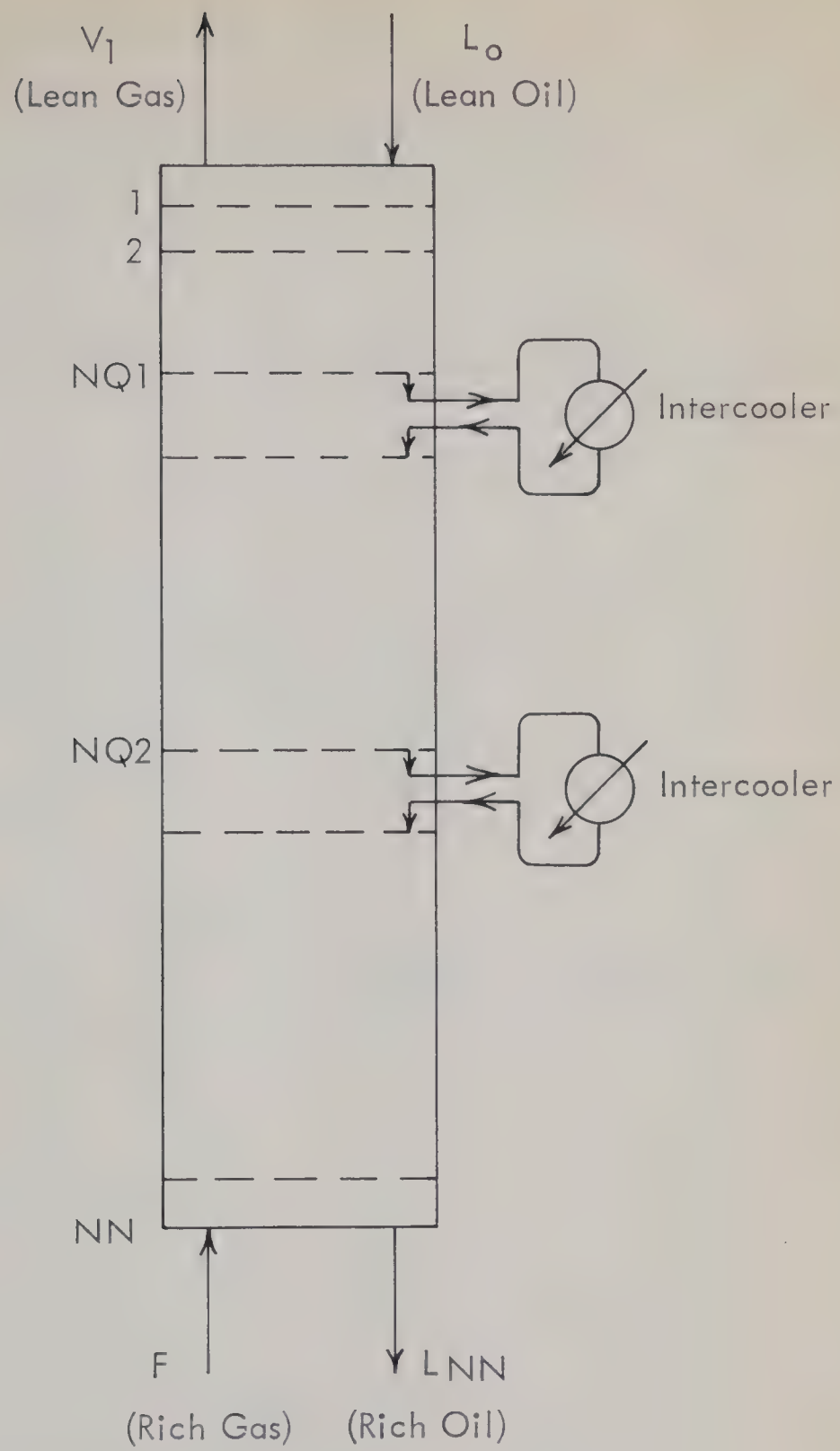


FIGURE 1

1



FIGURE 2

3.2.2 Reboiled Absorber

The reboiled absorber of Figure 2 can similarly be shown to have $2N + 2C + 11$ degrees of freedom. This is determined by considering the component sections of the column as follows:

	<u>Variables</u>
(N-1) equilibrium stages = (N-1)(2C+6) =	$2NC + 6N - 2C - 6$
1 feed stage	$3C + 8$
1 stream divider	$C + 5$
1 equilibrium reboiler	$C + 4$
2 sections of the column requiring the specification of the number of plates in each	2
Number of variables	$2NC + 6N + 3C + 13$
There are $2(N-1) + 3$ inter-streams which give restricting conditions equal to $(2(N-1)+3)(C+2)$ or $2NC + 4N + C + 2$	
Subtracting these restricting conditions from the number of unit variables leaves $2N + 2C + 11$ degrees of freedom which are to be taken up as follows:	
Heat leak on each stage	N
Pressure on each stage	N
Streams L_o and F - Rate, Temperature, pressure and composition	$2C + 4$
Number of stages above and below the feed stage	2
Pressure and heat leak in stream divider	2
Rate of streams SSR and V(1)	2
Pressure in reboiler	1
	$2N + 2C + 11$

The addition of a side stream to either of the columns would introduce two additional degrees of freedom which would normally be taken up by the specification of the rate and location of that side stream. Similarly, in the case of the addition of an interheater/cooler, the specification of the duty and location would take up the extra degrees of freedom introduced.

3.3 Solution of Equations (A,B) by the Theile-Geddes Method

The equations of the Theile-Geddes computational procedure for solving equations (A,B) are developed below for any component 'i'. The component subscript will not be used but is to be understood.

3.3.1 Reboiled Absorber

A material balance around the bottom of the column in Figure 2 and plate 'n' may be written -

$$\frac{l_{NN}}{b} = S_{NT} + (1 + \frac{w}{b}) = (\frac{L_{NN}}{L_{NN} - SSR}) (S_{NT} + 1) \quad (3-7a)$$

$$\frac{l_{n-1}}{b} = S_n (\frac{l_n}{b}) + C_1 \quad NN \geq n > NF_1 \quad (3-7b)$$

$$\frac{l_{MNF_1}}{b} = S_{NF_1} (\frac{l_{NF_1}}{b}) + C_1 + \frac{v_F}{b} - \frac{f}{b} \quad n = NF_1 \quad (3-7c)$$

$$\frac{l_{n-1}}{b} = S_n (\frac{l_n}{b}) + C_1 - \frac{f}{b} \quad NF_1 > n > 1$$

where

$$C_1 = 1 + \frac{w}{b} = 1 + \left(\frac{SSR}{L_{NN}} \right) \left(\frac{l_{NN}}{b} \right) \quad (3-7d)$$

and

$$S_n = \frac{V_N^{K_{in}}}{L_n} \quad (3-7e)$$

In this set of equations the variable 'b' is unknown. The only variables specified are f_n and v_F while S_n can be calculated from the iteration variables L_n , V_n and T_n . In order to solve for 'b' the equivalent values of $l_n/b + C_1$, as defined by equations (3-7), are substituted successively in the material balance equations beginning with l_{NN}/b . This gives, at $n = 1$

$$\frac{l_o}{b} = AA + BB \times C_1 + CC \frac{v_F}{b} - DD \frac{F}{b} \quad (3-8)$$

where

$$AA = S_1 \cdot S_2 \cdot S_3 \cdot \dots \cdot S_{NT}$$

$$BB = (S_1 \cdot S_2 \cdot \dots \cdot S_{NN}) + (S_1 \cdot S_2 \cdot \dots \cdot S_{NN-1}) + \dots \\ + (S_1) + 1$$

$$CC = S_1 \cdot S_2 \cdot \dots \cdot S_{MNF_1}$$

$$DD = (S_1 \cdot S_2 \cdot \dots \cdot S_{MNF_1}) + (S_1 \cdot S_2 \cdot \dots \cdot S_{MNF_{1-1}}) \\ + \dots + (S_1) + 1$$

By overall material balance,

$$b = \frac{l_o + F}{C_1 + \frac{d}{b}} \quad (3-9)$$

Replacing 'b' in equation (3-8) with its equivalent, the result is

$$\left(\frac{b}{d}\right)_{up} = \frac{ZT}{(AA + BB \times C_1)(l_o + f) - (C_1 \times ZT)} \quad (3-10)$$

where

$$ZT = l_o - CC \times v_F + DD \times f$$

Having solved for the ratio $(b/d)_{up}$, the value of 'b' can be found from the material balance (3-9). With the value of 'b' calculated thus, the plate to plate values of l_n/b can now be calculated using equations (3-7).

An alternate method of finding the component molal flow rates on each plate is to draw the material balances around the top of the column and plate 'n' as follows:

$$\frac{v_n}{d} = AF_{n-1} \left(\frac{v_{n-1}}{d}\right) + \left(1 - \frac{l_o}{d}\right) \quad NF_1 > n \geq 2 \quad (3-11a)$$

$$\frac{v_{NF_1}}{d} = AF_{MNF_1} \left(\frac{v_{MNF_1}}{d}\right) + \left(1 - \frac{l_o}{d}\right) + \frac{l_F}{d} - \frac{f}{d} \quad (3-11b)$$

$$n = NF_1$$

$$\frac{v_n}{d} = AF_{n-1} \left(\frac{v_{n-1}}{d}\right) + \left(1 - \frac{l_o}{d}\right) - \frac{f}{d} \quad (3-11c)$$

$$NT \geq n > NF_1$$

where

$$AF_{n-1} = \frac{L_{n-1}}{V_{n-1} \times K_{n-1}} \quad (3-11d)$$

the absorption factor of the component on plate n-1.

Of the variables in this equation 'd' is unknown. l_F , f and l_o are specified, while AF_{n-1} can be determined from the iteration variables L_{n-1} , V_{n-1} , and T_{n-1} . In order to determine 'd', the equivalent of v_{n-1}/d is substituted successively in formulas (3-11) beginning with $v_1/d = 1$. This gives, at plate NF1

$$\frac{v_{NF1}}{d} = AA + BB(1 - \frac{l_o}{d}) + \frac{l_F}{d} - \frac{f}{d} \quad (3-12)$$

where

$$\begin{aligned} AA &= (AF_{MNF1} \cdot \dots A_1) \\ BB &= (AF_{MNF1} \cdot \dots A_1) + (A_{MNF1} \cdot \dots A_2) \\ &\quad + \dots + A_{MNF1} + 1 \end{aligned}$$

The value of v_{NF1}/d is alternatively available from the relationships

$$\frac{v_{NF1}}{d} = \frac{b}{(-)} \left(\frac{v_{NF1}}{b} \right) \quad \text{and} \quad \frac{v_{NF1}}{b} = \frac{l_{NF1}}{b} S_{NF1} \quad (3-13)$$

From the overall material balance,

$$d = \frac{f + l_o}{\frac{b_i}{(-)} \frac{C_1}{d_i} + 1} \quad (3-14)$$

Substituting (3-13) and (3-14) into (3-12) we obtain

$$\frac{b}{(-)} \text{down} = \frac{(AA + BB)(f + l_o) + CJ}{\frac{v_{NF1}}{b} (f + l_o) - C1 \times CJ} \quad (3-15)$$

where

$$CJ = l_F - f - BB \times l_o$$

Using the ratio $(b/d)_{\text{down}}$ thus determined, 'd' can be calculated from the material balance (3-14). Using this value of 'd', the quantities l_o/d , f/d and l_F/d can be calculated and the plate to plate values of v/d determined from equations (3-11).

Round-Off Error

As mentioned by Hardy et al(15), the values of $(b/d)_{\text{up}}$ and $(b/d)_{\text{down}}$ give identical results for most problems, while the values of b/d calculated by the equations

$$\left(\frac{b}{d}\right)_{\text{top}} = \frac{1}{\frac{l_1}{b} \times S_1}$$

and

$$\left(\frac{b}{d}\right)_{\text{NF1}} = \frac{\frac{v_{\text{NF1}}}{d}}{\frac{l_{\text{NF1}}}{b} \times S_{\text{NF1}}}$$

do not. The ratios $(b/d)_{\text{down}}$ and $(b/d)_{\text{up}}$ contain negligible round-off error, due to their method of calculation, but the same is not true of $(b/d)_{\text{top}}$ and $(b/d)_{\text{NF1}}$. To determine which one of the latter contains the least amount of round-off error, the "round-off error ratios"

$$R_{\text{TOP}} = \frac{\left(\frac{b}{d}\right)_{\text{top}}}{\left(\frac{b}{d}\right)_{\text{up}}} \quad (3-16a)$$

$$R_{\text{NF1}} = \frac{\left(\frac{b}{d}\right)_{\text{NF1}}}{\left(\frac{b}{d}\right)_{\text{down}}} \quad (3-16b)$$

are calculated. The ratio which most closely approaches unity is the one with the least round off error. If R_{TOP} is closest

to unity, then the l_n/b calculation is the most correct for this component and the v_n/b will be calculated from the l_n/b by the equation

$$\frac{v_n}{d} = \frac{l_n}{b} \times S_n \times \left(\frac{b}{d}\right)_{up}$$

If R_{BOT} is closest to unity, then the v_n/d calculation is the most correct and the l_n/b will be calculated from the v_n/d by the equation

$$\frac{l_n}{b} = \frac{v_n}{d} \times \frac{AF_n}{\left(\frac{b}{d}\right)_{down}}$$

While it would appear that the identical results for $(b/d)_{up}$ and $(b/d)_{down}$ reported by Hardy et al(15) make the calculation of both of them unnecessary, this is not the case. In problems involving components heavier, say than octane, and a large number of plates, the successive substitution of the stripping and absorption factors in the determination of $(b/d)_{up}$ and $(b/d)_{down}$ produces numbers outside the limits of the computer. Because the computer replaces the numbers outside its limits with those limits the computation of $(b/d)_{up}$ may be in error, making the calculation of $(b/d)_{down}$ unnecessary.

3.3.2 Absorber

A material balance for any component 'i' drawn around the bottom of the column in Figure 1 and any plate 'n-1' may be written

$$\frac{l_{n-1}}{b} = S_n \left(\frac{l_n}{b} \right) + 1 - \frac{f}{b} \quad (3-17)$$

where

$$S_n = \frac{V_n K_n}{L_n} \quad NN \leq n \leq 2$$

In this equation, the only variable specified is 'f' while the term S_n can be calculated from the iteration variables L_n, V_n and T_n . To solve for 'b', l_n/b is substituted successively into equation (3-17), beginning with $l_{NN}/b = 1$. This results, at $n-1$, in the expression

$$\frac{l_o}{b} = AA + BB \left(1 - \frac{f}{b} \right) \quad (3-18)$$

where

$$\begin{aligned} AA &= (S_1 \cdot S_2 \cdot \dots \cdot S_{NN}) \\ BB &= (S_1 \cdot S_2 \cdot \dots \cdot S_{NN-1}) + (S_1 \cdot S_2 \cdot \dots \cdot S_{NN-2}) \\ &\quad + \dots + S_1 + 1 \end{aligned}$$

By overall material balance,

$$b = \frac{l_o + F}{1 + \frac{d}{b}} \quad (3-19)$$

Replacing 'b' in equation (3-18) with this equivalent gives

$$\left(\frac{b}{d} \right)_{up} = \frac{l_o + BB \times f}{(AA + BB)(l_o + f) - (l_o + BB \times f)} \quad (3-19a)$$

With this value of $(b/d)_{up}$ in terms of known variables, 'b' can be solved for using the material balance equation (3-19).

The plate to plate calculation of l_{n-1}/b can be carried out by substitution of the value of 'b' into equation (3-17).

By drawing a material balance for any component around the top of the column and any plate n , the following equation may be written

$$\frac{v_n}{d} = AF_{n-1} \left(\frac{v_{n-1}}{d} \right) + 1 - \frac{l_o}{d} \quad (3-20)$$

In this equation, the variable l_o is known while the term AF_{n-1} can be calculated from the iteration variables V_n , L_n and T_n . By successive substitution of the value of v_n/d in equation (3-20), beginning with $v_1/d = 1$, the equation below is obtained.

$$\frac{v_{NN+1}}{d} = AA + BB \left(1 - \frac{l_o}{d} \right) \quad (3-21)$$

where

$$AA = (AF_{NN} \cdot \dots \cdot AF_2 \cdot AF_1)$$

$$BB = (AF_{NN} \cdot \dots \cdot AF_2) + (AF_{NN} \cdot \dots \cdot AF_3) + \dots + A_{NN} + 1$$

However, $v_{NN+1} = f$ and, by material balance,

$$d = \frac{l_o + f}{1 + \frac{b}{d}} \quad (3-22)$$

Substituting these values of 'd' and 'f' into equation (3-21) gives

$$\frac{b}{\left(\frac{-}{d} \right)_{\text{down}}} = \frac{AA + BB(l_o + f) - (f + BB \times l_o)}{(f + BB \times l_o)} \quad (3-22a)$$

Using the value of $(b/d)_{\text{down}}$ thus determined, 'd' can be calculated from the material balance (3-22).

With this value of 'd', the plate to plate calculation of v_n/d can be carried out using equation (3-20).

Round-Off Error

As mentioned in the section about round-off errors in the reboiled absorber calculational procedure, the b/d ratios calculated from the values of l_n/b and v_n/d by the equations

$$\left(\frac{b}{d}\right)_{\text{top}} = \frac{l_1}{S_1 \times \frac{l_1}{b}}$$

$$\left(\frac{b}{d}\right)_{\text{bottom}} = \frac{v_{NN}}{d} \times AF_{NN}$$

may contain round-off error while $(b/d)_{\text{up}}$ and $(b/d)_{\text{down}}$ do not. To determine which of $(b/d)_{\text{top}}$ and $(b/d)_{\text{bottom}}$ contains the least round-off error, the round-off error ratios R_{TOP} and R_{BOT} are calculated and compared for their proximity to unity.

$$R_{\text{TOP}} = \frac{\left(\frac{b}{d}\right)_{\text{top}}}{\left(\frac{b}{d}\right)_{\text{up}}} \quad R_{\text{BOT}} = \frac{\left(\frac{b}{d}\right)_{\text{bottom}}}{\left(\frac{b}{d}\right)_{\text{down}}} \quad (3-23)$$

The b/d ratio and the corresponding variable l_n/b or v_n/d , which appear in the round-off error ratio most closely approaching unity, are used in all subsequent calculations involving component molal flow rates.

At this point, with the equations (A,B) solved to give values for l_n/b_i and v_n/d_i , the two different methods of solving the equations (C) and (D) will be described. These methods are the "bubble point" method and the "sum rates" method.

3.4 The Bubble Point Method

3.4.1 General

This method, which calculates the new temperature profile by a bubble point calculation of each stage, and which determines the new flow profile by enthalpy balances, uses a forcing technique called the θ convergence method to adjust the material balance solution so that it satisfies a top product specification. This technique and the enthalpy balances used will be described in subsequent subsections. The bubble point calculation will not be described but may be seen in the subprograms BUBPT in Annex 5 to Appendix C and Annex 5 to Appendix D.

3.4.2 θ Convergence Technique

The θ convergence method, proposed by Lyster et al(27) has been adapted to the problem of absorbers(14) and reboiled absorbers(15). The θ procedure assists convergence by adjusting the solution of the material balance equation in each iteration so that the specification $\sum_{i=1}^{NCP} d = DS$, is satisfied. This is done in the following manner. (Component subscripts will be omitted in all subsequent equations but should be understood.)

To relate the calculated value of b/d , $(b/d)_{ca}$, with the corrected value of b/d , $(b/d)_{co}$, (which satisfies the specification of top product, (DS) , and the overall and component material balances), an empirical expression was developed, as defined by

$$\left(\frac{b}{d}\right)_{co} = \theta \left(\frac{b}{d}\right)_{ca} \quad (3-24)$$

The component material balance requires

$$f + l_o = d_{co} + b_{co} = d_{co} \left(1 + \left(\frac{b}{d}\right)_{co}\right)$$

which by rearrangement and the substitution of the equivalent of $(b/d)_{co}$ from equation (3-24) gives

$$d_{co} = \frac{f + l_o}{\left(1 + \theta \left(\frac{b}{d}\right)_{ca}\right)} \quad (3-25)$$

The specification of top product requires

$$DS = \sum d_{co} = \sum \left(\frac{f + l_o}{\left(1 + \theta \left(\frac{b}{d}\right)_{ca}\right)} \right) \quad (3-26)$$

The desired value of θ is the one which makes both sides of equation (3-26) equal or gives $g(\theta) = 0$ where

$$g(\theta) = \sum d_{co} - DS$$

In order to solve for the θ which will make $g(\theta) = 0$, Newton's approximation is applied where

$$\theta_{K+1} = \theta_K - \frac{g(\theta)}{g'(\theta)}$$

and

$$g'(\theta) = \frac{g(\theta)}{\partial \theta} = - \sum \left(\frac{(f + l_o) \left(\frac{b}{d}\right)_{ca}}{\left(1 + \theta \left(\frac{b}{d}\right)_{ca}\right)^2} \right)$$

When the correct value of θ to make $g(\theta) = 0$ has been found by successive applications of Newton's method, the corrected values of d and b can be calculated from equation (3-25) and

the expression

$$b_{co} = \theta \left(\frac{b}{d} \right)_{ca} d_{co}$$

respectively.

The corrected mole fractions for each plate are then calculated as follows:

$$x_n = \frac{\left(\frac{l_n}{b} \right)_{ca} \times b_{co}}{\sum \left(\frac{l_n}{b} \right)_{ca} \times b_{co}} \quad (3-27)$$

$$y_n = \frac{\left(\frac{v_n}{d} \right)_{ca} \times d_{co}}{\sum \left(\frac{v_n}{d} \right)_{ca} \times d_{co}} \quad (3-28)$$

The Reboiled Absorber with Side Streams

The determination of θ factors for columns with side streams is described by Lyster et al(28). In addition to the θ required to correct $(b/d)_{ca}$, a θ is needed to correct the $(w/d)_{ca}$ ratio.

$$\left(\frac{b}{d} \right)_{co} = \theta_1 \left(\frac{b}{d} \right)_{ca} \quad (3-29a)$$

$$\left(\frac{w}{a} \right)_{co} = \theta_2 \left(\frac{w}{d} \right)_{ca} \quad (3-29b)$$

Also, the side stream product specification (SSR) must be satisfied in addition to the top product specification and the overall and component material balances. The requirement of the component material balance is

$$f + l_o = d_{co} + b_{co} + w_{co} = d_{co} \left(1 + \left(\frac{b}{d} \right)_{co} + \left(\frac{w}{d} \right)_{co} \right)$$

which may be rearranged using equation (3-29) to give

$$d_{co} = \frac{f + l_o}{(1 + \theta_1 \left(\frac{b}{d}\right)_{ca} + \theta_2 \left(\frac{w}{d}\right)_{ca})}$$

$$w_{co} = \theta_2 \left(\frac{w}{d}\right)_{ca} \times d_{co}$$

Satisfying the top product specification requires

$$\sum d_{co} = DS$$

while satisfying the side stream product specification requires

$$\sum w_{co} = SSR$$

These expressions may be formed into the 'g' functions

$$g_1(\theta_1, \theta_2) = \sum d_{co} - DS$$

$$g_2(\theta_1, \theta_2) = \sum w_{co} - SSR$$

The values of θ_1 and θ_2 desired are those which make $g_1(\theta_1, \theta_2)$ and $g_2(\theta_1, \theta_2)$ equal to zero. These values are found by applying the Newton-Raphson method.

$$\begin{aligned} g_1(\theta_1, \theta_2)_{k+1} &= g_1(\theta_1, \theta_2)_k + \frac{\partial g_1(\theta_1, \theta_2)}{\partial \theta_1} \Delta \theta_1 \\ &\quad + \frac{\partial g_1(\theta_1, \theta_2)}{\partial \theta_2} \Delta \theta_2 \end{aligned} \quad (3-30a)$$

$$\begin{aligned} g_2(\theta_1, \theta_2)_{k+1} &= g_2(\theta_1, \theta_2)_k + \frac{\partial g_2(\theta_1, \theta_2)}{\partial \theta_1} \Delta \theta_1 \\ &\quad + \frac{\partial g_2(\theta_1, \theta_2)}{\partial \theta_2} \Delta \theta_2 \end{aligned} \quad (3-30b)$$

Evaluating the partial derivatives and rearranging the equations (3-30) with use of the fact that $g_1(\theta_1, \theta_2)_{k+1}$ and $g_2(\theta_1, \theta_2)_{k+1}$ are zero for the proper values of θ_1 and θ_2 , the following expressions are obtained.

$$\begin{aligned}
 -g_1(\theta_1, \theta_2)_k &= - \frac{\sum ((f + 1_o) (\frac{b}{d})_{ca}) \Delta \theta_1}{\sum (1 + \theta_1 (\frac{b}{d})_{ca} + \theta_2 (\frac{w}{d})_{ca})^2} \\
 &\quad - \frac{\sum ((f + 1_o) (\frac{w}{d})_{ca}) \Delta \theta_2}{\sum (1 - \theta_1 (\frac{b}{d})_{ca} - \theta_2 (\frac{w}{d})_{ca})^2} \\
 -g_2(\theta_1, \theta_2) &= - \frac{\sum (\theta_2 (\frac{w}{d})_{ca} (f + 1_o) (\frac{b}{d})_{ca}) \Delta \theta_1}{\sum (1 + \theta_1 (\frac{b}{d})_{ca} + \theta_2 (\frac{w}{d})_{ca})^2} \\
 &\quad + \left[\sum \left(\left(\frac{w}{d} \right)_{ca} d_{co} \right) - \frac{\sum (\theta_2 (\frac{w}{d})_{ca})^2 (f + 1_o)}{\sum (1 + \theta_1 (\frac{b}{d})_{ca} + \theta_2 (\frac{w}{d})_{ca})^2} \right]
 \end{aligned}$$

These equations may be solved simultaneously for θ_1 , θ_2 .

This method of correcting θ_1 and θ_2 is repeated until the values of θ_1 and θ_2 make g_1 and g_2 equal to zero. Then the mole fractions on each plate are corrected according to equations (3-27) and (3-28).

3.4.3 Enthalpy Balances for the Absorber

In the bubble point method, correction of the vapor and liquid profiles are made at the end of each iteration by means of enthalpy balances. The stream enthalpies required

can be determined either in the 'conventional' or 'constant composition' methods, both of which are described below.

Conventional Enthalpy Balances

An enthalpy balance around the top of the column in Figure 1 and any plate 'n' gives

$$H_n V_n + L_o h_o = H_1 V_1 + L_{n-1} h_{n-1} + \sum_{j=1}^{n-1} Q_j \quad (3-31)$$

A material balance drawn in the same manner yields

$$V_n + L_o = V_1 + L_{n-1}$$

or

$$L_{n-1} = V_n + L_o - V_1 \quad (3-32)$$

Substituting the equivalent for L_{n-1} into (3-31) gives

$$V_n = \frac{V_1 (H_1 - h_{n-1}) - L_o (h_o - h_{n-1}) + \sum_{j=1}^{n-1} Q_j}{H_n - h_{n-1}} \quad (3-33)$$

$$NN > n > 2$$

Having calculated V_n , L_{n-1} can be found from equation (3-32).

Constant Composition Enthalpy Balances

Holland(25) has stated that the term $(H_n - h_{n-1})$ can produce considerable round-off error in problems containing only very light and heavy components such as absorbers. This term is sensitive to changes in temperature and composition because H_n and h_{n-1} are approximately equal in cases where the vapor phase is made up of very light components while the liquid is composed of heavy components. Because of this near

equality, small errors in the determination of the terms of the denominator in equation(3-32) cause large errors in the evaluation of V_n . Holland devised the constant composition method to avoid this problem in the following way:

Writing the enthalpy balance around the top of the column in Figure 1 and plate 'n-1',

$$H_n V_n + h_o L_o = H_1 V_1 + h_{n-1} L_{n-1} + \sum_{j=1}^{n-1} Q_j \quad (3-34)$$

where

$$H_n V_n = \sum_{i=1}^{NCP} H_{ni} v_{ni} = \sum H_{ni} (l_{n-1,i} + v_{1,i} - l_{o,i})$$

or

$$H_n V_n = \sum_{i=1}^{NCP} H_{ni} (L_{n-1} x_{n-1,i} + V_1 y_{1,i} - L_o x_{o,i}) \quad (3-35)$$

Substituting the value of $V_n H_n$ from equation (3-35) into equation (3-34) gives

$$\begin{aligned} L_{n-1} H(x_{n-1})_n + V_1 H(y_1)_n - L_o H(x_o)_n + L_o h_o \\ = V_1 H_1 + L_{n-1} h_{n-1} + \sum_{j=1}^{n-1} Q_j \end{aligned}$$

which may be simplified to

$$L_{n-1} = \frac{V_1 (H_1 - H(y_1)_n) - L_o (h_o - H(x_o)_n) + \sum_{j=1}^{n-1} Q_j}{H(x_{n-1})_n - h_{n-1}} \quad (3-36)$$

$$NN \geq n \geq 2$$

$$V_n = V_1 + L_{n-1} - L_o \quad NN \geq n \geq 2 \quad (3-37)$$

where

$$H(x_{n-1})_n = \sum_{i=1}^{NCP} H_{n_i} x_{n-1_i}$$

$$H(x_o)_n = \sum_{i=1}^{NCP} H_{n_i} x_{o_i}$$

$$H(y_1)_n = \sum_{i=1}^{NCP} H_{n_i} y_{1_i}$$

The vapor and liquid profiles are determined using equations (3-36) and (3-37). In this method the denominator consists of the difference between the enthalpy of a vapor and the enthalpy of a liquid of the same composition, or approximately the latent heat of vaporization of the mixture. This precludes the possibility of the denominator being very small or of negative value as is a possibility in the case of conventional enthalpy balances. It is recognized that the equation (3-35) is only correct when the material balance (3-37) is correct, i.e. when convergence is obtained. It is possible that this requirement assists in the forcing of convergence.

3.4.4 Enthalpy Balances for the Reboiled Absorber

As is the case with absorbers, there are the two methods of evaluating the corrected vapor and liquid flow profiles in the solution of reboiled absorbers. The equations are developed in the same manner as described in Section 3.4.3 for absorbers. Consequently, only the final equations for reboiled absorbers are given below.

Conventional Enthalpy Balances

$$V_n = \frac{V_1(H_1 - h_{n-1}) - L_o(h_o - h_{n-1}) + \sum_{j=1}^{n-1} Q_j}{H_n - h_{n-1}} \quad (3-38a)$$

$$MNF1 \geq n \geq 2$$

$$L_{n-1} = V_n + L_o - V_1 \quad MNF1 \geq n \geq 2 \quad (3-38b)$$

$$V_{MNF1} = \frac{V_1(H_1 - h_{MNF1}) - L_o(h_o - h_{MNF1}) - FV(HY - h_{MNF1}) + \sum_{j=1}^{MNF1} Q_j}{H_{MNF1} - h_{MNF1}} \quad (3-38c)$$

$$L_{MNF1} = V_{MNF1} + L_o + FV - V_1 \quad (3-38d)$$

$$V_n = \frac{V_1(H_1 - h_{n-1}) - L_o(h_o - h_{n-1}) - F(H_F - h_{n-1}) + \sum_{j=1}^{n-1} Q_j}{H_n - h_{n-1}} \quad (3-38e)$$

$$NT \geq n \geq MNF1$$

$$L_n = V_n + L_o + F - V_1 \quad NT \geq n \geq MNF1 \quad (3-38f)$$

$$\begin{aligned} \text{Reboiler Load} &= V_1 H_1 + L_{NT} h_{NT} + SSR \times h_{NN} - F H_F \\ &\quad - L_o h_o + \sum_{j=1}^{NN} Q_j \end{aligned} \quad (3-38g)$$

Constant Composition Enthalpy Balances

$$L_{n-1} = \frac{V_1(H_1 - H(y_1)_n) - L_o(h_o - H(x_o)_n) + \sum_{j=1}^{n-1} Q_j}{H(x_{n-1})_n - h_{n-1}} \quad (3-39a)$$

$$MNF1 \geq n \geq 2$$

$$V_n = V_1 + L_{n-1} - L_O \quad MNF1 \geq n \geq 2 \quad (3-39b)$$

$$L_{MNF1} = \frac{V_1 (H_1 - H(y_1)_{MNF1}) - L_O (h_O - H(x_O)_{MNF1}) - FV (H_F - H(y_F)_{MNF1}) + \sum_{j=1}^{MNF1} Q_j}{H(x_{MNF1})_{MNF1} - h_{MNF1}} \quad (3-39c)$$

$$V_{MNF1} = V_1 + L_{n-1} - FV - L_O \quad (3-39d)$$

$$L_{n-1} = \frac{V_1 (H_1 - H(y_1)_n) - L_O (h_O - H(x_O)_n) - F (H_F - H(z_F)_n) + \sum_{j=1}^{n-1} Q_j}{H(x_{n-1})_n - h_{n-1}} \quad (3-39e)$$

$$V_n = V_1 + L_{n-1} - L_O - F \quad NT \geq n > MNF1 \quad (3-39f)$$

$$\begin{aligned} \text{Reboiler Load} &= V_1 H_1 + L_{NT} h_{NT} + SSR \times h_{NN} - F H_F \\ &\quad - L_O h_O + \sum_{j=1}^{NN} Q_j \end{aligned} \quad (3-39g)$$

where

$$H(z_F)_n = \sum_{i=1}^{NCP} H_{ni} z_{Fi}$$

$$H(y_F)_n = \sum_{i=1}^{NCP} H_{ni} y_{Fi}$$

3.5 The Sum Rates Calculational Procedure

In the sum rates method of solution of equations (C) and (D), the component molal flow rates on each plate are summed to determine the new flow profiles and then the new temperature profile is determined by means of enthalpy balances on each plate. The mole fractions of the components on each plate are calculated from the equations

$$x_{in} = \frac{l_{in}}{\sum_i l_{in}} \quad (3-40a)$$

$$y_{in} = \frac{v_{in}}{\sum_i v_{in}} \quad (3-40b)$$

The flow profiles are given by

$$L_n = \sum_{i=1}^{NCP} l_{in} \quad (3-41a)$$

$$V_n = \sum_{i=1}^{NCP} v_{in} \quad (3-41b)$$

The enthalpy balances used in the determination of the change to be made in the temperature of each plate are

$$E_1 = -Q_1 - FEH_1 + L_1 h_1 + V_1 H_1 - V_2 H_2 \quad (3-42a)$$

$$E_n = -Q_n - FEH_n - L_{n-1} h_{n-1} + L_n h_n + V_n H_n - V_{n+1} H_{n+1} \quad (3-42b)$$

$$E_{NN} = -Q_{NN} - FEH_{NN} - L_{NN-1} h_{NN-1} + L_{NN} h_{NN} + V_{NN} H_{NN} \quad (3-42c)$$

If the existing temperature profile were correct, E_n for all values of 'n' would be zero. To adjust the temperatures so that this is true, Newton's approximation is used where

$$(E_n)_{k+1} = (E_n)_k + dE_n \quad (3-43)$$

with

$$dE_1 \approx -E_1 = \frac{\partial E_1}{\partial t_1} dt_1 + \frac{\partial E_1}{\partial t_2} dt_2 \quad (3-44a)$$

$$\begin{aligned} dE_n \approx -E_n &= \frac{\partial E_n}{\partial t_{n-1}} dt_{n-1} + \frac{\partial E_n}{\partial t_n} dt_n \\ &+ \frac{\partial E_n}{\partial t_{n+1}} dt_{n+1} \end{aligned} \quad (3-44b)$$

$$dE_{NN} \approx -E_{NN} = \frac{\partial E_{NN}}{\partial t_{NN-1}} dt_{NN-1} + \frac{\partial E_{NN}}{\partial t_{NN}} dt_{NN} \quad (3-44c)$$

where

$$\frac{\partial E_n}{\partial t_{n-1}} = - \frac{\partial L_{n-1} h_{n-1}}{\partial t_{n-1}} = -L_{n-1} \left(\frac{\partial h_{n-1}}{\partial t_{n-1}} \right)$$

$$\frac{\partial E_n}{\partial t_n} = \frac{\partial L_n h_n}{\partial t_n} + \frac{\partial V_n H_n}{\partial t_n} = L_n \left(\frac{\partial h_n}{\partial t_n} \right) + V_n \left(\frac{\partial H_n}{\partial t_n} \right)$$

$$\frac{\partial E_n}{\partial t_{n+1}} = - \frac{\partial V_{n+1} H_{n+1}}{\partial t_{n+1}} = -V_{n+1} \left(\frac{\partial H_{n+1}}{\partial t_{n+1}} \right)$$

The terms $\partial H/\partial t$ and $\partial h/\partial t$ are, in fact, the heat capacities of the vapor and liquid streams at temperature t . They are

evaluated in this work by numerical differentiation of enthalpy over a small increment of temperature. Because the desired value of $(E_n)_{k+1}$ is zero, the equation (3-44b) for plate 'n' could be written

$$-b_{n-1} \Delta t_{n-1} + a_n t_n - d_{n+1} \Delta t_{n+1} = -E_n \quad (3-45)$$

where

$$b_{n-1} = L_{n-1} \frac{\partial h_{n-1}}{\partial t_{n-1}}$$

$$d_{n+1} = V_{n+1} \frac{\partial H_{n+1}}{\partial t_{n+1}}$$

$$a_n = L_n \frac{\partial h_n}{\partial t_n} + V_n \frac{\partial H_n}{\partial t_n}$$

When written in matrix form the equations (3-45) form a tri-diagonal matrix which may be solved by the method described by Friday(13). Eliminating Δt_{n-1} from the set of equations, the n^{th} member becomes

$$\Delta t_n = E'_n + d'_{n+1} \Delta t_{n+1} \quad (3-46)$$

where the values of E'_n and d'_{n+1} are

$$E'_n = \frac{-E_n + b_{n-1} E'_{n-1}}{a_n - b_{n-1} d'_n}$$

$$d'_{n+1} = \frac{d_{n+1}}{a_n - b_{n-1} d'_n}$$

For stage 1

$$E'_1 = - \frac{E_1}{a_1}$$

$$d'_2 = \frac{d_2}{a_1}$$

Using the equation (3-46), the values of Δt_n may be solved for each plate, beginning with

$$\Delta t_{NN} = E'_{NN}$$

The change in temperature is then applied to the existing temperature profile and a new iteration begun.

The equations apply equally to the absorber and the reboiled absorber, differing only in the values of Q_n and FEH_n applied at the various plates. For the absorber

FEH_1 = the enthalpy of the absorber oil stream

FEH_{NN} = the enthalpy of the wet gas stream

Q_n = the intercooler/interheater load for any plate n

For the reboiled absorber

FEH_1 = the enthalpy of the absorber oil stream

FEH_{NT} = the enthalpy of the feed stream

Q_n = the intercooler/interheater load on any plate n

Q_{NT} = the reboiler load

FEH_{NF1} = the enthalpy of the feed stream

4. DATA SOURCES

4.1 Natural Gas Association of America Polynomial K Data

The Equilibrium Ratio Data Book of the Natural Gas Association of America contains a series of charts representing the equilibrium ratios of twelve hydrocarbons according to the convergence pressure principle of Hadden. These charts, for methane through decane, have been "curve-fitted" for both temperature and pressure variations. The resulting analytical expressions, which are presented below, have a double set of coefficients for each component at each convergence pressure.

$$\left(\frac{T}{1000}\right) (\ln K)(P) = a_0 + a_1 \left(\frac{T}{1000}\right) + a_2 \left(\frac{T}{1000}\right)^2 + a_3 \left(\frac{T}{1000}\right)^3$$

$$\text{where } a_0 = b_{00} + b_{01} \left(\frac{\ln P}{10}\right) + b_{02} \left(\frac{\ln P}{10}\right)^2 + \dots b_{06} \left(\frac{\ln P}{10}\right)^6$$

$$a_1 = b_{10} + b_{11} \left(\frac{\ln P}{10}\right) + b_{12} \left(\frac{\ln P}{10}\right)^2 + \dots b_{16} \left(\frac{\ln P}{10}\right)^6$$

$$a_2 = \dots$$

$$a_3 = \dots$$

The coefficients " b_{ij} " are available from the N.G.A.A. in list and card form. The obvious advantage of this source of K data is its utility. In the case of both the absorber and the reboiled absorber, the convergence pressure will remain reasonably constant throughout the column. This is so

because the convergence pressure is dependent on the liquid phase weight fractions which are dominated on all plates by the absorber oil. Working at essentially one convergence pressure, it is possible to change the pressure of the column when desired without the further curve-fitting that is necessary with the usual temperature variable polynomial fit.

Convergence pressures were calculated by the method of Winn (29) on a lightest component free basis. The data in this correlation covers the convergence pressures from 600 to 20,000 as presented in the NGAA Equilibrium Ratio Data Book.

4.2 Yen and Alexander Enthalpy Correlation

Yen and Alexander (20), using improved Lydersen-Greenkorn-Hougen charts, present a series of equations for the machine computation of vapour and liquid enthalpies for hydrocarbons. The charts, which correlate the enthalpy departure of a component from ideal gas behaviour with its reduced pressure and reduced temperature according to a modified theory of corresponding states, were divided into four regions: the super-heated vapour region; the saturated vapour line; the saturated liquid line; and the sub-cooled liquid region. For each of these regions equations were

developed to represent the enthalpy departure at the following values of z_c : $z_c = 0.23$; $z_c = 0.25$; $z_c = 0.27$; $z_c = 0.29$. The expressions for the last three of the regions at the various values of z_c are presented in Appendix A. The super-heated region is not included as it is not applicable to the separation problems considered here.

Yen and Alexander (20) state that the analytical expressions reproduce the data of the charts with a maximum error of ± 0.1 BTU/lb., mole $^{\circ}\text{R}$, while the charts themselves have an average deviation of 5 BTU/lb. from the literature data used in their preparation.

Mixture enthalpies are determined by using Kay's rule to give the psuedo-critical properties of the mixture and then substituting these properties in the appropriate equation.

$$z_c^1 = \sum_{i=1}^{NCP} x_i z_{c_i}$$

$$T_c^1 = \sum_{i=1}^{NCP} x_i T_{c_i}$$

$$P_c^1 = \sum_{i=1}^{NCP} x_i P_{c_i}$$

The ideal gas state enthalpies are calculated from an equation of the form,

$$(H_i^0 - H_o) = AH + BH \left(\frac{T}{1000}\right) + CH \left(\frac{T}{1000}\right)^2 + DH \left(\frac{T}{1000}\right)^3$$

with $T = ^{\circ}\text{R}$

where the coefficients AH, BH, CH, and DH are determined from a curve fit of the data of Rossini (30) using Forsythe polynomials as described in Lapidus (31). Values of these coefficients are listed in Appendix A, Table 1.

The limits, within which this correlation is valid are:

- a. Saturated Vapour $0.1 < P_r < 1.0$
- b. Saturated liquid $0.01 < P_r < 1.0$
- c. Sub cooled liquid $0.01 < P_r < 30$
 $0.5 < T_r < 1.0$

where T_r and P_r are the reduced properties of the mixture or component being treated.

4.3. The Chao-Seader Correlation

The Chao-Seader correlation (17) for predicting K data, extended by Edminster et al (21), provides a consistent set of equilibrium and enthalpy data for hydrocarbon mixtures. The method of calculating the data is suitable for the machine computation of multi-stage, multi-component separation problems. The correlation as described by Erbar (8) is used in this work.

The Chao-Seader correlation determines K values from the relationship

$$K_i = \frac{\mu_i \gamma_i}{\phi_i}$$

where μ_i is the f/p ratio for the liquid phase
 γ_i is the liquid phase activity coefficient
 ϕ_i is the vapour phase fugacity coefficient

The f/p ratio for the liquid phase of a component is a well defined quantity when the component is actually a liquid. However, when the pure component is a vapour at the conditions of interest, the liquid f/p ratio has no actual meaning. To assist the handling of mixtures at conditions of this sort, the correlation of the liquid fugacity coefficient has been extended by calculations from experimental data to include such conditions. This has been done within the frame work of the modified principle of corresponding states of Pitzer. The first term on the right hand side of equation 4-1 represents the fugacity coefficient of a simple fluid while the second term represents the correction for real fluids.

μ_i is calculated from the formulae

$$\log \mu_i = \log \mu_i^0 + w \log \mu_i^1 \quad (4.1)$$

where $\log \mu_i = A_0 + A_1/T_r + A_2 T_r + A_3 T_r^2 + A_4 T_r^3 +$

$$(A_5 + A_6 T_r + A_7 T_r^2) P_r + (A_8 + A_9 T_r^2) P_r^2 - \log P_r$$

$$\log \mu_i = 4.23893 - 8.65808 T_r - 1.22060/T_r^3 - 3.15224$$

$$T_r - 0.025 (P_r - 0.6)$$

The generalized constants used in the calculation of μ are the same for all components other than the following five: methane, nitrogen, hydrogen, carbon dioxide, and hydrogen sulfide. Each of these components has its own set of constants. The components oxygen and carbon monoxide use the same constants as methane.

γ_i is calculated from the Scatchard-Hildebrand equation

$$\ln \gamma_i = V l_i (\delta_i - \delta_m)^2$$

where

$$\delta_m = \sum \frac{\delta_i x_i V l_i}{x_i V l_i} \quad (4.2)$$

The use of this equation includes the assumption that liquid solutions of hydrocarbons are regular solutions ie: solutions with zero excess entropy of mixing. The term δ_m is the average solubility parameter of the solution as defined by equation 4.2.

ϕ is determined using the Redlich-Kwong equation of state in the form

$$z = \frac{1}{1-h} + \frac{A_m^2}{B_m} \left(\frac{h}{1+h} \right) \text{ where } h = \frac{B_m P}{z} \quad (4.3)$$

$$A_m = \sum y_i A_i$$

$$B_m = \sum y_i B_i$$

$$A_i = \left(\frac{0.4278}{P_c T_r^{2.5}} \right)^{0.5}$$

$$B_i = \frac{0.0867}{P_c T_r}$$

z is solved for by trial and error, formula 4.3 being implicit in z. Once having calculated z

$$\ln \phi_i = (z-1) \frac{B_i}{B_m} - \ln (z - B_m P) + \frac{A_m^2}{B_m} \left(\frac{A_i}{A_m} - \frac{B_i}{B_m} \right) \times (\ln (1+h))$$

4.3.2 Enthalpy Values

Vapour phase enthalpies are calculated from the following equation:

$$H_m = \sum_i y_i H_i^0 + \frac{3}{2} \frac{A_m^2}{B_m} \ln \left(1 + \frac{B_m P}{z} \right) + 1 - z$$

The first term of this expression represents the enthalpy of the mixture at the ideal gas state of zero pressure while the second term represents the deviation from ideality due to pressure. It is derived from the Redlich-Kwong equation of state.

Liquid phase enthalpies are calculated from the following relationships

$$h_m = \sum_i h_i$$

$$h_i = H_i^0 - RT_r^2 T_c \left[\left(\frac{\partial \ln \mu_i}{\partial T_r} \right)_P + \left(\frac{\partial \ln \gamma_i}{\partial T_r} \right)_{P, x_i} \right]$$

$$\text{where } \left(\frac{\partial \ln \mu_i}{\partial T_r} \right)_P = 2.303 \left[- \frac{A_1}{T_r^2} + A_2 + z A_3 T_r^2 + 3 A_4 T_r + \right.$$

$$\left. (A_6 + 2 A_7 T_r) P_r + A_9 P_r^2 + \omega_i (A_{11} - A_{12} / T_r^2 + 3 A_{13} T_r^2) \right]$$

$$\left(\frac{\partial \ln \gamma_i}{\partial T_r} \right)_{P, x_i} = \frac{V l_i}{RT_r^2 T_c} (\alpha_m - \alpha_i)^2 \times 1.8$$

Again the first term of the equation represents the ideal gas state enthalpy while the second term represents the deviation from ideality.

The values of the constants, of z , and of the compositions are those which are used in the calculation of the K ratios already discussed. H_i^0 , the ideal gas state enthalpy of a component is evaluated from a cubic equation in temperature, the constants of which are listed in Table 5, Annex A, for each of the components encountered in this work.

$$H_i^0 = A H_i + (B H_i) T + (C H_i) T^2 + (D H_i) T^3 \text{ with } T \text{ in } ^\circ F$$

4.3.3 Hypothetical Components

A means of handling complex hydrocarbon fractions, such as heavy absorber oil, is described by Erbar(8) as modified from Cavett's method (6). The minimum information required for a component is the API gravity, the molecular weight and, either the mean average boiling point or the molal

average boiling point and the cubic average boiling point. From this information the data required for the equilibrium and enthalpy calculations are produced by use of the following equations:

The mean average boiling point, if it is not specified, is calculated from the cubic average and the molal average boiling point which must be specified in this case.

$$BP_{ma} = \frac{BP_{ca} + BP_{mla}}{2}$$

The liquid molal volume V_l is calculated from

$$V_{l_i} = \frac{MW}{d@25^{\circ}C}$$

where $d @ 25^{\circ}C = (0.98907) (Sp. gr. @ 60^{\circ}F)$

$$\text{where } (Sp.gr. @ 60^{\circ}F) = \frac{141.5}{131.5 + ^{\circ}API}$$

Pseudo-critical properties: The pseudo-critical temperature is calculated by the equation:

$$T_c = a_0 - a_1T + a_2T^2 + a_3T^3 + a_4AT + a_5AT^2 + a_6A^2T^2$$

T = the molal average boiling point, if available, or the mean average boiling point in $^{\circ}R$.

A = API gravity

The pseudo-critical pressure is calculated in psia by the equation:

$$\text{Log } P_c = b_0 + b_1 T + b_2 T^2 + b_3 T^3 + b_4 A T + b_5 A T^2 + b_6 A^2 T + b_7 A^2 T^2$$

where T = mean average boiling point in °R.

A = API gravity

If either the critical temperature or the critical pressure of the fraction have been specified, the respective calculation of the psuedo property is bypassed. See Sub-program PHYS Appendix D, Annex A, for the equations above with the constants included.

The accentric factor ω is computed according to Edminster's equation

$$\omega = \frac{3}{7} \left(\frac{\log(p_c/14.7)}{T_c/T_b - 1.0} \right) - 1.0$$

The solubility parameter is calculated as follows:

$$\delta_i = \left(\frac{\Delta H_{v, 25^\circ C} - 592.4}{Vl_i} \right)^{1/2}$$

where $\Delta H_{v, 25^\circ C} = \left(\frac{T_c - 537}{T_c - t_b} \right)^{0.38} \times (\Delta H_v)_{NBP}$

$$\Delta H_{v, NBP} = (7.58 + 4.571 \log T_b) \times T_b$$

The constants required for the ideal gas state enthalpy equation

$$H_i^0 = A H_i + B H_i \times T + C H_i \times T^2 + D H_i \times T^3$$

are calculated from the following equations:

$$AH = MW(C_0 + C_1A + C_2A^2 + C_3A^3 + C_4K + C_5K^2 + C_6K^3 + C_{18}AK)$$

$$BH = MW(C_7 + C_8A + C_9A^2 + C_{10}A^3 + C_{11}K + C_{12}K^2 + C_{13}K^3)$$

$$CH = MW(C_{14} + C_{15}A)$$

$$DH = MW(C_{16} + C_{17}A)$$

where $A = ^\circ\text{API}$

K = the U.O.P. characterization factor

The limitations of the Chao-Seader correlation are:

- a. For hydrocarbons (excluding methane)
Reduced temperature ... 0.5 to 1.3 based on pure component critical temperatures
Pressure ... up to 2,000 psia but not to exceed P_r of 0.8 based on the psuedo-reduced pressure of the mixture
- b. For light gases (H_2 and CH_4)
Temperature ... -100°F to 0.93 psuedo-reduced temperature of the equilibrium liquid mixture but not to exceed 500°F .
Pressure ... up to 8,000 psia
Composition ... up to about 20 mole % of dissolved gas in the liquid.

5. DESCRIPTION OF PROGRAMS

5.1 Absorber - Bubble Point Procedure

5.1.1 Specifications

The specifications required for this program are those of Section 3.2.1, namely:

- a. adiabatic operation,
- b. column pressure,
- c. composition, rate, pressure of streams L_0 and F_1
- d. Temperature of stream L_0 ,
- e. rate of stream V_1 ,
- f. number of stages,
- g. convergence tolerances for θ , V_1 , and temperature change from iteration to iteration.

An initial assumption of the temperature, liquid and vapour profiles is required to initiate the calculational procedure. This is true for all the other programs as well and, although this statement is not repeated with each set of specifications, it is to be understood.

5.1.2 Capability of the Program

This program will provide a solution for an absorber problem i.e. the temperature profile, the liquid and vapour flow profiles, and the product compositions are calculated.

FLOW DIAGRAM
BUBBLE POINT METHOD

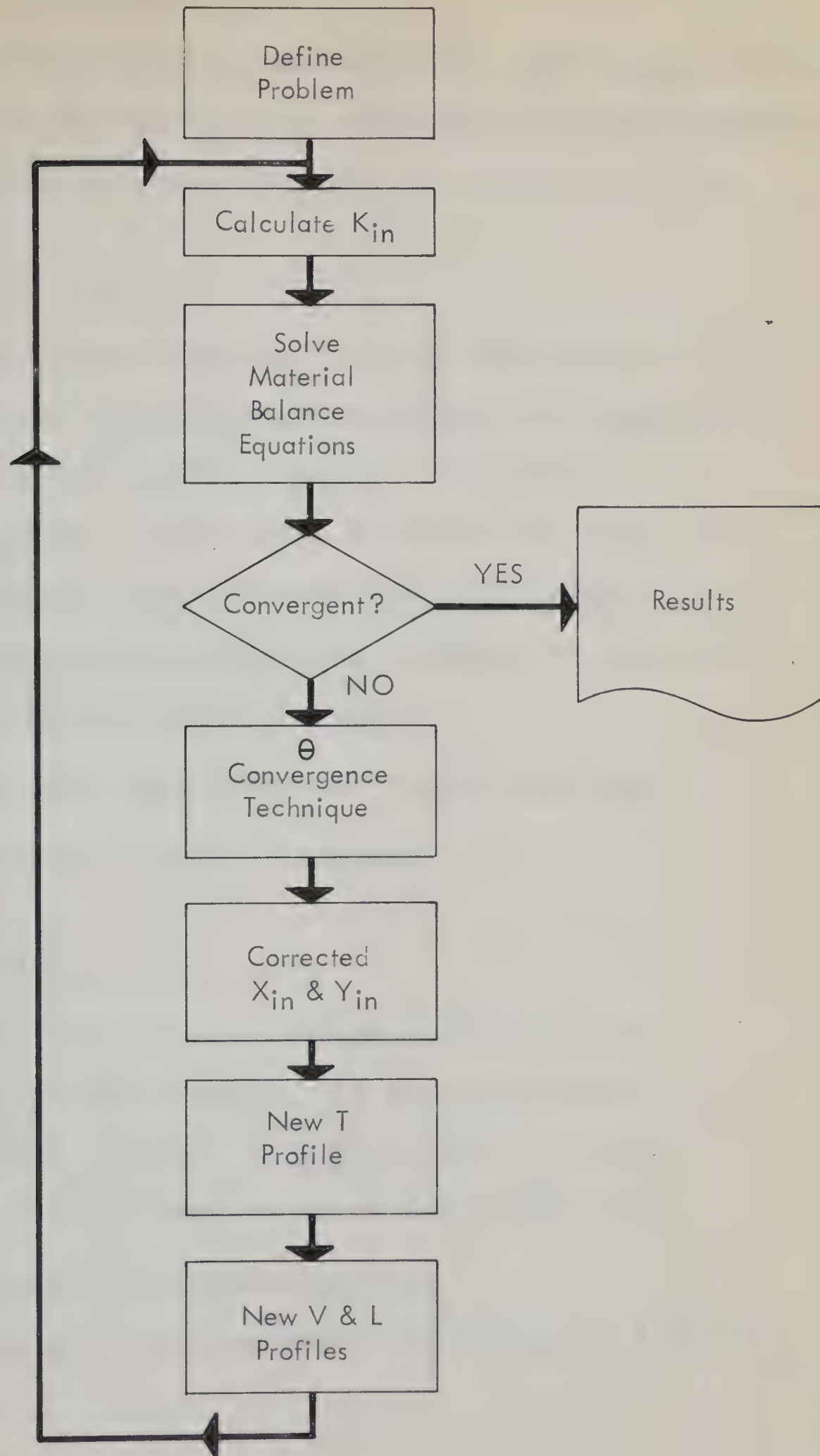


FIGURE 3

5.1.3 Sequence of Computation

The sequence of calculation for the solution of the absorber using the bubble point procedure is shown schematically in the flow diagram, Figure 3. In step form, the sequence is:

a. Define problem

- (1) Read in problem data. If the Chao Seader correlation is being used, calculate the physical constants for any hypothetical components in subprogram PHYS. If the NGAA K values are being used, calculate the coefficients for the polynomial in temperature at the operating pressure of the column using subprogram PHYS (K Const)
- (2) Calculate mole fractions in feed streams.
- (3) Print out problem statement.

b. Calculate $K_{i,n}$

- (1) Calculate the equilibrium ratios for each component on each plate. If the Chao-Seader correlation is used, calculate ideal K ratios for the first iteration using subprogram KIDL.

c. Solve material balance equations

- (1) Calculate the absorption and stripping factors

for each plate using equations 3.7e and 3.11d.

(2) Calculate the $(\frac{b}{d})_{up}$ ratio using equation 3.19a.

(3) Calculate the $(\frac{b}{d})_{down}$ ratio using equation 3.22a.

(4) Calculate $\frac{l}{b}$ using equation 3.17.

(5) Calculate $\frac{v}{d}$ using equation 3.20.

(6) Calculate round-off error ratios using equation 3.23.

(7) Correct $\frac{l}{b}$ or $\frac{v}{d}$ throughout the column.

for each component in turn.

d. Convergent

(1) If overhead product, θ and temperature change between iterations satisfy convergence tolerances, calculate the feed temperature by trial and error and print out the solution to the separation problem.

e. θ Convergence

(1) Calculate the θ necessary to force convergence, according to section 3.4.2.

f. Corrected $x_{i,n}$ and $y_{i,n}$

(1) Calculate the corrected component mole fractions on each stage using equations 3.27 and 3.28.

g. New temperature profile

(1) Calculate the new temperature profile by deter-

mining the bubble point of the liquid stream from each plate using subprogram BUBBT.

h. New vapour and liquid profiles

(1) determine the new vapour and liquid profiles using stream enthalpies calculated by;

(a) the conventional method with the Chao-Seader correlation (equation 3.31)

(b) the constant composition method with the Yen and Alexander enthalpy correlation (equations 3.36).

i. Return to step b. with the new temperature, vapour and liquid profiles.

5.2 Reboiled Absorbers - Bubble Point Procedure

5.2.1 Specifications

The specifications required for this program are those detailed in Section 3.2.2, namely:

- a. adiabatic operation,
- b. operating pressure
- c. composition, rate, temperature, and pressure of streams L_0 and F ,

- d. rates of streams V_1 and SSR
- e. number of stages and feed stage number,
- f. convergence tolerances for θ , V_1 , SSR, and temperature change from iteration to iteration.

5.2.2 Capabilities

This program will determine temperature profile, the vapour and liquid profiles, product stream compositions, and the reboiler load for a specified reboiled absorber.

5.2.3 Sequence of Computation

The sequence of calculations in the solution of the reboiled absorber by the bubble point procedure is much the same as that for the absorber. For this reason, the computational sequence, which is described below in step form, has the same flow diagram, Figure 3.

a. Define problem

(1) Read in problem data. If the Chao-Seader correlation is being used calculate hypothetical component physical properties using subprogram PHYS. If the NGAA K ratios are being used, calculate the temperature coefficients at the column pressure using subprogram PHYS (K const.)

(2) Calculate the vapour/liquid fraction of the feed, feed enthalpy, and the mole fractions of the feed according to its condition.

(3) Print out the problem statement.

b. Calculate $K_{i,n}$

(1) Calculate the equilibrium ratio for each component on each plate. If the Chao-Seader correlation is being used, calculate ideal K ratios for the first iteration using subprogram KIDL.

c. Solve material balance equations

(1) Calculate the AF_n and S_n using equations 3.7e and 3.11d.

(2) Calculate $(\frac{b}{d})_{up}$ using equation 3.10.

(3) Calculate $(\frac{b}{d})_{down}$ using equation 3.15.

(4) Calculate $\frac{l_n}{b}$ using equation 3.7.

(5) Calculate $\frac{v_n}{d}$ using equation 3.11.

(6) Calculate round off error ratios using equation 3.16.

(7) Correct $\frac{l_n}{b}$ or $\frac{v_n}{d}$ throughout the column.

d. Convergent?

(1) If overhead product, side stream product, θ ,

and temperature satisfy convergence tolerances,
print out the solution.

e. θ Convergence

(1) Calculate the θ necessary to force convergence
according to Section 3.4.2.

f. Corrected $x_{i,n}$ and $y_{i,n}$

(1) Calculate the corrected component mole fractions
on each plate according to equations 3.27 and 3.28.

g. New T profile

(1) Calculate the new temperature profile by deter-
mining the bubble point of each liquid stream
using subprogram BUBPT.

h. New V and L Profiles

(1) determine the new liquid and vapour flow profiles
using the stream enthalpies calculated by

- a. the conventional method if the Chao-Seader
correlation is being used (equation 3.38)
- b. the constant composition method if the Yen
and Alexander enthalpy correlation is being
used (equation 3.39)

i. Calculate the reboiler duty according to equation 3.38g
or 3.39g.

j. Return to step b. with the new temperature, vapour and
liquid profiles and begin a new iteration.

5.3 Absorber - Sum Rates Procedure

5.3.1 Specifications

The specifications for this program are the same as those for the absorber by bubble point procedure with the following exception:

- a. The feed temperature is specified and the rate of V_1 is not specified.

5.3.2 Capabilities

This program will calculate the temperature profile, the liquid and vapour flow profiles, product stream compositions, and product stream rates for the specifications of section 5.3.1.

5.3.3 Sequence of Computation

The sequence of calculation for the solution of an absorber problem by use of the sum rates procedure is shown schematically in Figure 4 and is described in step form below.

- a. Define the problem
 - (1) Read in problem data. If using the Chao-Seader correlation, calculate the physical properties of the hypothetical components using subprogram PHYS.

FLOW DIAGRAM
SUM RATES METHOD

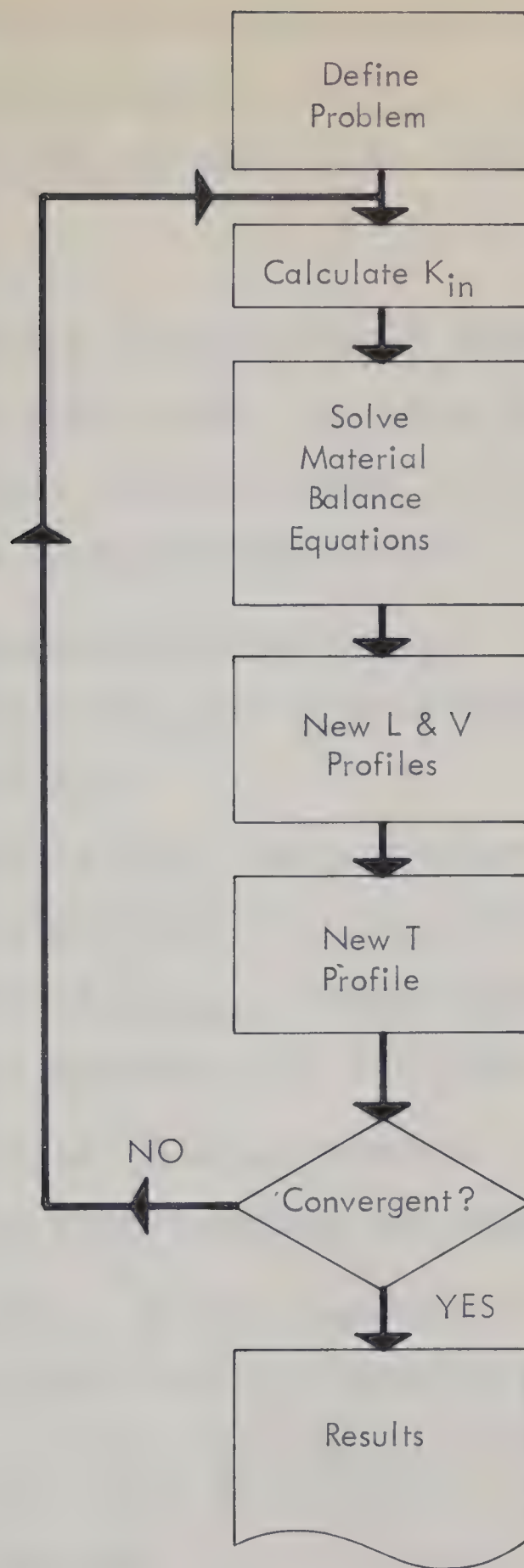


FIGURE 4

(2) Calculate feed rates, feed mole fractions,
and feed enthalpies

(3) Print out the problem statement.

b. Calculate $K_{i,n}$

(1) Calculate the equilibrium ratios for each component on each plate. If using the Chao-Seader correlation, calculate ideal K ratios for the first iteration using subprogram KIDL.

c. Solve material balance equations

(1) Calculate AF_n and S_n from equations 3.7e and 3.11d.

(2) Calculate $(\frac{b}{d})_{up}$ using equation 3.19a for absorbers, equation 3.10 for reboiled absorbers.

(3) Calculate $(\frac{b}{d})_{down}$ using equation 3.22a for absorbers, equation 3.15 for reboiled absorbers.

(4) Calculate $\frac{l_n}{b}$ using equation 3.17 for absorbers equation 3.7 for reboiled absorbers.

(5) Calculate $\frac{v_n}{d}$ using equation 3.20 for absorbers, using equation 3.11 for reboiled absorbers.

(7) Correct $\frac{l_n}{b}$ or $\frac{v_n}{d}$ throughout the column.

d. New L and V profiles

(1) Calculate the new liquid and vapour profiles

using equation 3.41.

(2) Calculate the new component mole fractions using equation 3.40.

e. New T profile

(1) Determine the new temperature profile using the sum rates method described in Section 3.5.

f. Convergent?

(1) If the change in temperature on each plate is greater than the specified convergence tolerance return to step b. and begin new iteration.

g. Results.

(1) Print out the solution to the separation problem in the form of component molal flow rates in product streams, flow profiles and temperature profile.

5.4 Reboiled Absorber - Sum Rates Procedure

5.4.1 Specifications

The specifications for this program are the same as those for the reboiled absorber by the bubble point procedure with the following exception:

a. the reboiler load is specified and the overhead product is not specified.

5.4.2 Capabilities

This program SHOULD calculate the unique temperature profile, liquid and vapour profiles, product stream compositions and rates for the specifications of Section 5.4.1.

5.4.3 Sequence of Computation

The sequence of calculations described in section 5.3.3 is used.

6. RESULTS

In this section, a brief description of the example problems attempted and several tables for comparison of results will be presented. Complete problem statements (with the initial assumptions made) and complete results are presented in Appendix F.

6.1 Example Problem Statements

6.1.1 Example Problem No. 1 - Absorber

This absorber problem is described by Hardy et al (14) as number 16, and is solved by Friday (10) as problem 4.

The problem specifications are:

Components	f (moles)	l_o (moles)
CH_4	70	0
C_2H_6	15	0
C_3H_8	10	0
nC_4	4	0
nC_5	1	0
nC_8	0	20

Pressure = 300 psia

$V_1 = 85.0$ moles

Number of Theoretical Stages = 8

Lean Oil Temperature 90°F

This problem is solved using

a. Bubble Point Procedure with

(1) Polynomial data of Hardy et al (14)

(2) NGAA and Yen and Alexander data

(3) Chao-Seader data

b. Sum Rates Procedure

(1) Polynomial data of Hardy et al (14)

(2) Chao-Seader data

The constants and equations for the polynomial equilibrium and enthalpy data of Hardy et al (14) are listed in Table 2 of Appendix A.

6.1.2 Example Problem #2 - Absorber

This absorber problem, described and solved by a short cut method by Smith (26) as Problem 8.1, and solved rigorously by Friday (10) has the following specifications.

<u>Components</u>	<u>F</u> <u>(Moles)</u>	<u>l_o</u> <u>(Moles)</u>
CH ₄	28.5	0.0
C ₂ H ₆	15.8	0.0
C ₃ H ₈	24.0	0.0
nC ₄	16.9	2.21
nC ₅	14.8	5.52
nC ₈	0	102.67

Pressure = 60 psia

V₁ = 57.8 moles

Number of Theoretical Stages = 4

Temperature of lean oil = 90°F

This problem is solved using

a. Bubble point procedure

(1) NGAA data and Yen and Alexander data

(2) Chao-Seader Data

b. Sum Rates Procedure

(1) Chao-Seader Data

6.1.3 Example Problem #3 - Absorber with Intercooler

The operating data and a shortcut solution for an existing absorber are given by Jackson and Sherwood(22). The specifications as calculated from these data for Trial 1 are as follows:

Component	F (lb.moles)	l_o (lb.moles)
H ₂ S	39.7	0
CH ₄ + L*	482.5	0
C ₂ H ₆	45.5	0
C ₂ H ₆	226.8	0
C ₃ H ₈	70.1	0
C ₃ H ₈	115.3	0
C ₄ H ₁₀	31.4	0
C ₄ H ₁₀	37.5	0
C ₅	26.4	0
L _o	0	846.7

Pressure = 91.5 psia

V₁ = 680.0 lb.moles

No. of theoretical stages = 7

Lean oil temperature = 55.5°F

Intercooler 1 on liquid stream from Plate 3

Heat removed by Intercooler 1 = 1,465,000 BTU

L _o	API	36.7°
	MW	185
	MnAvBP	495°F

L* indicates light components such as N₂, H₂ grouped with CH₄ in analysis by Jackson and Sherwood(22)

This problem was attempted by Friday(10) as example #7 and is partially solved by Sherwood and Pigford(32).

This problem is solved using

a) The Bubble Point procedure with

1) Chao-Seader data

6.1.4 Example Problem #4 - Absorber

The absorber of Example problem #3 was also operated without the intercooler to provide a comparison. The specifications, as calculated for Trial 2 of the Jackson and Sherwood report(22) are:

<u>Components</u>	<u>F</u>	<u>l_o</u>
H ₂ S	38.0	0
CH ₄ + L*	411.6	0
C ₂ H ₄	44.4	0
C ₂ H ₆	246.5	0
C ₃ H ₆	70.5	0
C ₃ H ₈	128.0	0
C ₄ H ₈	37.6	0
C ₄ H ₁₀	42.5	0
C ₅	29.9	0
L _o	0	838.0

Pressure = 91.5 psia

V_1 = 769 moles

No. of Theoretical stages = 7

Lean oil temperature = 56.4°F

L_o API 36.2
 MW 188
 MnAvBP 500°F

This problem is solved using

- a) The Bubble point procedure with
 - 1) Chao-Seader Data

6.1.5 Example Problem #5 - Absorber with Intercooler

The absorber problem solved by McNeese(11) has the following specifications

	Component	F (moles)	l _o (moles)
1	N ₂	40.85	0.58
2	CO ₂	11.60	2.44
3	H ₂ S	3.41	0.00
4	CH ₄	2377.61	102.54
5	C ₂ H ₆	461.42	118.61
6	C ₃ H ₈	147.73	21.08
7	iC ₄	7.26	0.02
8	nC ₄	19.04	0.02
9	iC ₅	1.73	0.02
10	nC ₅	1.64	0.02
11	nC ₆	0.60	0.00
12	nC ₇ + (=nC ₈)	0.00	253.00

Pressure = 1200 psia

V₁ = 2497.39

No. of theoretical stages = 6

Lean oil temperature = 20°F

Intercooler 1 on liquid from plate 3

Heat removed by intercooler = 236,344 BTU

This problem is solved using

a) Bubble point procedure with

1) Chao-Seader data

b) Sum Rates method with

1) Chao-Seader data

6.1.6 Example Problem #6 - Reboiled Absorber

This problem appears as example no. 11 in the paper by Hardy et al(15).

The specifications are

<u>Component</u>	<u>F_o</u>	<u>L_o</u>
CH_4	80.0	0
C_2H_6	6.66	0
C_3H_8	6.66	0
nC_4	6.66	0
nC_8	0.0	30.0

Pressure = 300 psia

V_1 = 95.0 moles

SSR = 15.0 moles

Lean oil temperature = 90°F

No. of theoretical stages (including absorber) = 10

Feed stage number = 6

Maximum vapor rate above feed plate = 200 moles

Minimum vapor rate above feed plate = 80 moles

Maximum vapor rate below feed plate = 100.0 moles

Minimum vapor rate below feed plate = 10.0 moles

This problem is solved using

a) Bubble point procedure with

1) NGAA and Yen and Alexander data

2) Chao-Seader data

It was attempted using the Sum rates method with

a) NGAA and Yen and Alexander data

b) Chao-Seader data but failed to converge to a unique solution

6.1.7 Example Problem 7 - Reboiled Absorber

The specifications for this problem were taken from a flow diagram for an existing gas plant design.

<u>Component</u>	<u>F_O</u>	<u>l_O</u>	<u>API</u>	<u>MWT</u>	<u>MnAvBP</u>
N ₂	0.7	0			
CO ₂	12.4	0			
CH ₄	167.4	0			
C ₂ H ₆	474.5	0			
C ₃ H ₈	440.2	0			
iC ₆	64.3	0			
nC ₄	128.8	0			
iC ₅	19.5	0			

<u>Component</u>	<u>F_O</u>	<u>L_O</u>	<u>API</u>	<u>MW</u>	<u>MnAvBP</u>
nC ₅	19.4	0			
C ₆	13.1	0			
Hypothetical 1	9.0	0.5	63.2	89.6	200°F
Hypothetical 2	5.3	2.1	57.3	103.6	265°F
Hypothetical 3	95.3	95.3	52.8	129.0	325°F
Hypothetical 4	149.9	149.9	47.3	145.0	380°F
Hypothetical 5	18.1	18.1	44.6	166.0	425°F

Pressure = 285 psia

V₁ = 677.0 moles

SSR = 0.0

Lean oil temperature = -5.0°F

Number of theoretical stage (incl. reboiler) = 16

Feed plate No. 6

Q_{RB} = 16,000,000 BTU/U.T.

This problem is solved using

a) Bubble Point procedure with

- 1) NGAA and Yen and Alexander data
- 2) Chao-Seader data (without hypothetical components)
- 3) Chao-Seader data (with hypothetical components)

6.2 Comparison Tables for Results

Table 1

Example Problem 1 - Hardy et al(14)

Absorber Bubble Point Solutions

Component	Hardy et al(14)	Polynomial Overhead Product	NGAA & YA CP (3000)	Chao Seader
C ₁	67.950	67.951	67.671	67.132
C ₂	12.282	12.284	12.615	12.257
C ₃	4.508	4.509	4.663	4.996
nC ₄	0.836x10 ⁻¹	0.083	.007	.211
nC ₅	0.660x10 ⁻³	0.000	.000	.000
nC ₈	0.174	0.173	.048	.406

Plate No.	Temperature Profile (°F)			
1	107.6	107.8	35.3	116.5
2	111.4	111.7	61.6	120.8
3	112.4	112.8	72.2	121.5
4	112.1	112.4	78.2	120.3
5	110.1	110.5	83.6	117.5
6	105.8	106.1	90.7	112.4
7	96.4	96.8	100.9	103.4
8	74.3	74.8	114.9	85.8

Plate No.	Vapor Rates Profile (moles/u.t.)			
1	85.0	85.0	85.0	85.0
2	89.8	89.8	99.4	90.5
3	90.5	90.5	102.3	91.2
4	90.7	90.8	103.2	91.5
5	90.9	91.0	103.3	91.7
6	91.2	91.3	103.0	92.1
7	91.8	91.8	102.3	92.8
8	93.1	93.2	101.6	94.3

Calculated feed Temperature (°F)	-7.0	133.9	38.3
Calculated top Product (moles/u.t.)	85.000	85.004	85.002
θ	.9999	1.0008	1.0002
IBM 7040 Computer time requires (min.)	0:40	0:34	5:59
No. of Iterations	34	18	16

Table 2

Example Problem 1 - Hardy et al(14)

Absorber Comparison of Sum Rates Results

Component	Hardy et al(14)	Polynomial Overhead Product	CS (mole/u.t.)	Friday(13)
C ₁	67.950	67.950	67.107	
C ₂	12.282	12.282	12.239	
C ₃	4.508	4.508	4.915	
nC ₄	.836x10 ⁻¹	.084	.209	
nC ₅	.660x10 ⁻³	.000	.000	
nC ₈	.174	.175	.411	

Plate No.	Temperature Profile (°F)			
1	107.6	108.1	117.2	117.5
2	111.4	111.9	121.6	125.8
3	112.4	113.0	122.2	130.2
4	112.1	112.6	121.0	132.8
5	110.1	110.7	118.1	134.2
6	105.8	106.3	112.9	133.8
7	96.4	96.8	103.8	130.3
8	74.3	74.7	86.2	119.5

Plate No.	Vapor Flow Profile (moles/u.t.)			
1	85.0	85.0	84.9	85.03
2	89.8	89.8	90.5	92.00
3	90.5	90.5	91.2	93.11
4	90.7	90.8	91.5	93.53
5	90.9	91.0	91.8	93.81
6	91.2	91.3	92.1	94.13
7	91.8	91.8	92.8	94.66
8	93.1	93.2	94.3	95.83

Calculated top Product moles/u.t.	84.996	84.999	84.94	85.03
Feed Temperature(°F)		-8.2	38.	81.
Convergence Criteria		ΔT<.01	ΔT<.01	
IBM 7040 Computer Time (min.)		0:05	0:42	
No. of Iterations		7	8	8

Table 3
Example Problem 2 - Smith(26)
Absorber Comparison of Bubble Point Results

Component	Smith(26)	Chao-Seader Overhead Product	NGAA C.P.=3000
			(mole fractions)
C ₁	.4725	.4746	.4788
C ₂	.2260	.2315	.2438
C ₃	.2251	.2210	.2503
nC ₄	.0434	.0424	.0227
nC ₅	.0168	.0172	.0046
C ₈	.0162	.0132	.0021

Plate No.	Temperature Profile (°F)		
1	109.0	112.3	50.9
2	118.0	121.9	82.6
3	126.0	128.4	110.0
4	130.0	125.3	153.1

Plate No.	Vapor Profile (moles/v.t.)		
1	57.8	57.8	57.8
2	76.1	74.0	98.1
3	82.6	79.4	112.0
4	88.8	84.1	118.9

Calculated Feed Temperature(°F)	33.3	356.0
Calculated Top Product	57.790	57.806
θ	.9996	1.0009
IBM 7040 Computer time (min:sec)	1:11	0:37
No. of Iterations	12	21

Table 4

EXAMPLE PROBLEM 2 - SMITH (26)

ABSORBER COMPARISON % SUM RATES RESULTS

Components	Smith	Chao-Seader	Friday (13)
	Overhead	Product (mole fractions)	
Methane	.4725	.4744	.3197
Ethane	.2260	.2314	.1782
Propane	.2251	.2209	.2730
n Butane	.0434	.0426	.1457
n Pentane	.0168	.0173	.0609
n Octane	.0162	.0134	.0225

<u>Plate No.</u>	<u>Temperature Profile (^oF)</u>		
1	109.0	112.8	109.6
2	118.0	122.3	119.4
3	126.0	128.5	127.4
4	130.0	124.8	131.6

<u>Plate No.</u>	<u>Vapour Flow Profile (mole/U.T.)</u>		
1	57.8	57.80	58.0
2	76.1	74.03	77.0
3	82.6	79.44	83.7
4	88.8	84.10	89.1

Calculated Overhead Product (moles/U.T.)	57.80	57.797	58.0
Feed Temp. (^o F)	90	29.5	90
Convergence Criteria		DT<.01	
Number of Iterations		9	12
IBM 7040 Computer Time (min.sec)		0:26	

Table 5
EXAMPLE PROBLEM 3 - JACKSON & SHERWOOD(22)
TRIAL 1

Comparison of Bubble Point Results

<u>Components</u>	<u>Jackson & Sherwood(22) Short cut calc.</u>	<u>Observed Mole</u>	<u>Chao-Seader</u>	
			<u>Mole Percent Absorbed</u>	
H ₂ S	38.7	36.7	63.9	64.4
CH ₄ + L	4.6	14.1	5.3	5.1
C ₂ H ₄	17.6	22.6	23.7	23.0
C ₂ H ₆	27.2	31.6	33.4	32.6
C ₃ H ₆	74.6	75.3	84.6	86.3
C ₃ H ₈	78.2	73.7	89.6	91.2
C ₄ H ₈	99.9	97.8	100.0	100.0
C ₄ H ₁₀	100.0	97.2	100.0	100.0
C ₅	100.0	100.0	100.0	100.0
Absorber Oil	0.0	0.0	0.0	0.0

<u>Plate No.</u>	<u>Temperature Profile (°F)</u>		
1	56.3	62.4	62.0
2		62.2	60.5
3		47.0	37.2
4		48.8	39.9
5		49.8	42.0
6		47.9	41.9
7	62.0	18.3	21.5

	<u>Vapor Profile (moles/U.T.)</u>		
1	680	680.0	680.0
2		761.2	759.4
3		778.0	774.9
4		808.2	812.2
5		822.0	830.6
6		831.8	846.9
7		851.0	871.2
Calculated Top Product (Moles/U.T.)	680	680.1	680.0
θ		1.0002	0.9993
Intercooler load (BTU/U.T.)	1,465,000	1,000,000	1,465,000
IBM 7040 Computer Time (min:sec)		16:55	7:17
No. of Iterations		37	15

Table 6

EXAMPLE PROBLEM 4 - JACKSON & SHERWOOD (22)

ABSORBER - TRIAL 2

Comparison of Results - Bubble Point Solution

Components	Jackson & Sherwood (22)		Chao Seader
	Short cut	Observed	
	Calc.		
Mole Percent Absorbed			
H ₂ S	30.1	26.3	29.66
CH ₄ +L*	3.6	2.8	3.23
C ₂ H ₄	13.4	11.5	11.06
C ₂ H ₆	21.9	13.6	15.53
C ₃ H ₆	56.7	51.7	47.53
C ₃ H ₈	61.5	54.6	54.08
C ₄ H ₈	99.8	97.4	99.31
C ₄ H ₁₀	100.0	96.1	99.63
C ₅	100.0	100.0	100.0
Absorber Oil	0.0	0.0	0.0

Plate No.	Temperature Profile (°F)	
1	58.7	71.1
2		75.1
3		77.1
4		78.9
5		81.4
6		85.4
7	75.7	89.6

Plate No.	Vapour Flow Profile (moles/U.T.)	
1	680.0	769.0
2		909.0
3		939.8
4		953.2
5		962.5
6		974.0
7		994.0

Calculated Feed		
Temperature °F		68.2
Calculated Top Product		
(moles/U.T.)		768.958
θ		0.9991
Intercooler load (BTU/U.T.)	0	0
IBM7040 Computer Time		
(Min:Sec)		7.17
No. of Iterations		20

Table 7

EXAMPLE PROBLEM 5 ----- McNEESE ABSORBER

Comparison of Results for Bubble Point &
Sum Rate Solution

Component	Bubble Point		Sum Rates
	McNeese(11)	Chao-Seader	Chao-Seader
<u>Overhead Product (Moles/U.T.)</u>			
N ₂	39.39	38.48	38.48
CO ₂	4.34	8.71	8.70
H ₂ S	0.95	0.80	.80
C ₁	2116.37	2087.43	2087.06
C ₂	311.28	329.70	329.56
C ₃	25.18	30.41	30.26
iC ₄	0.04	.06	.06
nC ₄	0.02	.04	.04
iC ₅	0.00	.00	.00
nC ₅	0.00	.00	.00
C ₆	0.00	.00	.00
C ₇ + (=C ₈)	0.00	3.20	3.18
Plate No.	Temperature Profile (°F)		
1	31.8	34.8	34.7
2	31.2	34.1	33.5
3	29.8	32.4	31.5
4	27.7	35.0	34.3
5	29.4	34.5	33.9
6	27.5	31.3	31.0
Plate No.	Vapour Profile (moles/U.T.)		
1	2497.59	2497.59	2498.14
2	2661.15	2671.45	2675.13
3	2685.00	2702.14	2708.16
4	2719.46	2752.95	2757.21
5	2778.10	2794.02	2794.24
6	2847.32	2873.24	2871.17
Calculated Feed Temperature(°F)		24.9	24.2
Calculated overhead product(mole/U.T.)		2498.83	2498.14
θ		1.0025	
Intercooler load (BTU/U.T.)		236344	236344
IBM7040 Computer Time (min:sec)		26.55	3:26
No. of Iterations		46	15

Table 8

EXAMPLE PROBLEM 6 - HARDY etal(15) REBOILED ABSORBER

Comparison of Bubble Point Results

<u>Component</u>	Hardy etal(15)	NGAA	Chao-Seader
	<u>Overhead Product (moles/U.T.)</u>		
C ₁	79.999	80.000	79.999
C ₂	6.655	6.665	6.665
C ₃	6.267	6.565	6.400
nC ₄	1.511	1.654	1.399
nC ₈	0.5667	0.113	.538

<u>Plate No.</u>	<u>Temperature Profile (°F)</u>		
1	129.4	64.4	125.8
2	147.2	117.0	136.5
3	157.2	143.1	137.5
4	161.1	156.9	127.7
5	156.3	162.1	93.1
6	268.3	259.7	263.7
7	331.3	293.9	303.4
8	394.2	351.0	356.8
9	455.5	439.4	429.2
10	495.3	502.5	489.7

<u>Plate No.</u>	<u>Vapour Profile(moles/U.T.)</u>		
1	95.0	95.0	95.0
2	106.8	117.6	104.0
3	110.5	126.4	106.5
4	113.1	131.6	108.9
5	115.6	135.4	113.9
6	21.4	41.4	76.5
7	57.0	75.7	49.1
8	67.0	75.6	52.8
9	70.0	74.2	52.7
10	84.6	106.0	65.2

Calculated Overhead			
Product(moles/U.T.)	94.996	94.997	95.001
Calculated Side Stream	14.996	14.994	14.997
Reboiler Duty(BTU/ U.T.)	984,000	937,537	893,139
θ ₁	0.998	1.0000	1.0000
θ ₂	0.990	1.0000	1.0003
IBM7040 Computer Time (min:sec)		0:29	8:00
No. of Iterations	27	19	36

Table 9

EXAMPLE PROBLEM 7 - REBOILED ABSORBER
Comparison of Results for Bubble Point Solution

Component	Design Results		NGAA		C.S.*		C.S.	
	Overhead		Product		(Moles)			
N ₂	0.7						0.7	
CO ₂	12.4	C ₁	180.5	180.00			12.4	
C ₁	167.4						167.4	
C ₂	466.3		465.1				455.2	
C ₃	30.0		31.1				41.1	
iC ₄	0.0		0.1				.2	
nC ₄	0.1		-				.1	
iC ₅	-		-				-	
nC ₅	-		-				-	
C ₆	-	C ₆	-	-			-	
200 NBP	-						-	
265 NBP	-	C ₇	-				-	
325 NBP	-	C ₉	0.1	0.2			.1	
380 NBP	0.1	C ₁₀	0.0	0.1			-	
425 NBP	-						-	

Plate No.	Vapor and Temperature Profile							
	V	T	V	T	V	T	V	T
1	677.0	72	677.0	55.0	677.0	79.6	677.0	74.0
2			1123.4	76.8	903.5	89.9	880.9	83.8
3			1121.1	88.2	922.8	94.9	898.4	88.4
4			1119.0	96.9	932.2	96.9	907.2	89.8
5			1117.3	104.7	947.2	93.0	922.3	85.1
6			943.6	108.0	974.7	81.5	944.0	76.4
7			950.8	120.5	1081.7	92.4	1006.0	86.4
8			953.0	127.8	1202.7	96.6	1114.7	90.2
9			952.8	136.2	1238.5	100.4	1148.0	93.4
10			952.4	146.4	1254.6	106.5	1163.2	98.3
11			952.8	157.8	1277.2	116.2	1181.3	106.5
12			954.5	168.8	1324.2	129.4	1215.8	118.6
13			957.0	178.3	1405.4	144.3	1279.7	133.6
14			959.6	186.6	1510.8	159.3	1375.6	149.4
15			960.5	197.0	1590.5	178.9	1463.7	168.8
16		257	946.3	260.8	1390.7	252.9	1316.4	238.4
Calculated Top Product			676.946		677.167			677.181
Reboiler Load			5,604,593		15,536,768			14,190,452
			1.000		1.003			1.004
IBM 7040 Computer Time								
(min:sec)			3:11		21:36			34:50
No. of Iterations			28		25			29

* (Same feed composition is used as with NGAA and Y and A solution)

7. DISCUSSION OF RESULTS

7.1 Comparison of Data Sources

7.1.1 Polynomial Data

The polynomial data of Hardy et al(14) was used to check the solutions of the developed programs against reported results. As can be seen in Tables 1 and 2, the results of Hardy et al are reproduced by both the bubble point and sum rates methods. This was not true when the reboiled absorber (Example 6) was tried. This problem would not converge using the polynomial data possibly because the K values calculated for octane at temperatures approaching 500°F became erratic. The results obtained for Example 6, using the NGAA and Yen and Alexander data and using Chao Seader data, indicate that the reboiled absorber program is functioning properly.

7.1.2 NGAA and Yen and Alexander Data

The results obtained for Example Problems 1 and 2 vary considerably from the literature values in all areas. This would seem to throw the reliability of the data into question. However, the results given for example problems 6 and 7 indicate that the data can produce reasonable results. It would appear, therefore, that the solution of absorbers is much more sensitive to the differences in data than that of the reboiled absorber.

7.1.3 Chao and Seader Correlation

The results of programs using the Chao and Seader correlation match the literature values reasonably well in all example problems. This agreement is perhaps best in the Example Problems 4 and 7 which illustrate the utility of a general correlation of this sort. The ability to handle components such as H_2S , N_2 , CO_2 , ethylene, propylene, butene, and hypothetical components, such as the absorber oil, is of great utility in the rigorous solution of absorber and reboiled separation problems.

7.1.4 Relative Timings

From the computing times for the IBM 7040 given in the Table 1, it can be seen that the time required increases with the complexity of the correlation. For an equivalent number of iterations, the Chao-Seader correlation requires roughly twelve times the computing time required by the NGAA and Yen and Alexander data. The time taken for any solution can, of course, be greatly reduced by an accurate set of initial assumptions. The necessity of this is particularly pointed out with the use of the Chao-Seader correlation. A general trend of predicting higher temperature profiles than the other data sources is shown by the Chao-Seader correlation. In most of the example problems this is in the order of $15^{\circ}F$.

In the bubble point method, the Chao Seader correlation causes long computing times when the bubble point calculation

is not solved quickly. This is because of the lengthy calculations necessary to calculate a value of the equilibrium ratio. Any means by which the speed of the bubble point calculation can be improved will produce a corresponding reduction in total computing time.

7.1.5 Evaluation of Data Used

a) The polynomial data, while providing a necessary basis for evaluating the performance of the programs and for comparing the example problem 1 to published results, is not a convenient way of providing data for the solution of absorbers and reboiled absorbers.

b) The NGAA equilibrium data and Yen and Alexander enthalpy data required the use of constant composition enthalpy balances to achieve convergence with the bubble point procedure. The constant composition method requires the use of partial molal enthalpies which are not obtained reliably from the Yen and Alexander data. Thus, the results obtained are questionable and the Chao Seader data is preferable.

Sum Rate programs for the solution of absorbers would not converge when used with NGAA and Yen and Alexander data.

c) The Chao Seader data is the best of the three data sets used in that it

- 1) has more utility by being able to handle a large range of components over a wide range of temperature and pressure.

2) does not require the use of the constant composition enthalpy balances.

3) reproduced operating data reasonably well in the one case available for comparison.

d) The data used has a very great bearing on the results obtained. This is borne out by the difference in results obtained for Problem No. 1. The statement made by Friday(10) that the sum rates method is more accurate than the bubble point method is not borne out by the results obtained for Problem No. 1. His results are different because he used different data.

7.2 Comparison of Methods

7.2.1 The Bubble Point Method

A very cursory examination of the times required for the solution of an absorber or reboiled absorber problem by the bubble method reveals that this method can be very expensive in terms of computing time. Attempts were made to reduce this time, particularly in the case of the bubble point procedure used in conjunction with the Chao-Seader data source.

A forcing technique in the form of a weighting factor for the temperature correction between iterations is necessary because of the over correction associated with the bubble point method. In problem 3, convergence was achieved using a weighting factor of 0.25 where

$$T_{k+1} = T_k + wt \times (T_{\text{bubble}} - T_k)$$

This convergence occurred after 47 iterations with a computing time of 17 minutes. A weighting factor of 0.1 was used with the same problem and convergence was not attained in 49 iterations with a computing time of 27 minutes. In the first case, there was no iteration past the 28th which required more than thirty trials to solve the bubble point on any stage, whereas, in the second case there were stages on which the bubble point calculation took more than thirty trials even in the last recorded iteration. This illustrates one way in which the bubble point calculation can be improved.

A 'stepped' weighting factor was used in one case in the following fashion

<u>Wt.</u>	<u>Iteration No.</u>
0.1	0 - 10
0.2	10 - 20
0.4	20 - 30
0.8	30 -

The program did not converge as the weighting factor of 0.8 was too severe. The use of the stepped weighting factor as shown above with the modification of using wt at 0.4 for all iterations after the twentieth did not produce any appreciable decrease in computing time for the problem attempted.

A convergence criteria involving the specification of the temperature change that can be allowed between two successive iterations before a solution can be assumed is required for the bubble point procedure. This is in addition

to the convergence criteria involving the top product, side product and θ . Table 10 shows the difference in results obtained for Example Problem 4 with the bubble point procedure using and not using the temperature change specification. While the percentages absorbed agree well, the vapor rates disagree by up to 15% in the center of the column. This makes the results obtained without the temperature restriction of limited use. However, the relative times required for solution may make this method attractive for some cases. The decision of which to use would depend on the economics of the situation. A comparison was made of the times required to reach a bubble point solution (polynomial data) for Example Problem 1, using different values of the temperature weighting factor, tolerance, product tolerance and bubble point tolerance. These appear in Table 11. With the introduction of a temperature change restriction, the tolerance on the bubble point calculation must be of a smaller magnitude than the tolerance allowed on the temperature change

7.2.2 Sum Rates Method

The computing times required for the solution of Problems 1, 2 and 5 by the sum rates method are quite low when compared to those required by the bubble point procedure. In Example 1, in particular, they are roughly one ninth of that required for the bubble point procedure using the Chao Seader data. Agreed, if the top product specification is to be satisfied, a series of trials at different feed temperatures

Table 10
Comparison of Results for Example Problem 4
With and Without ΔT Specification

W = with specification of $|T_{k+1} - T_k| < 0.1$

W/O = without ΔT specification

Component	Percentage Absorbed	
	W	W/O
H ₂ S	29.6	30.1
CH ₄ + L*	3.2	3.2
C ₂ H ₄	11.1	11.2
C ₂ H ₆	15.5	15.7
C ₃ H ₆	47.5	47.6
C ₃ H ₈	54.0	53.9
C ₃ H ₈	99.3	99.1
C ₄ H ₁₀	99.6	99.5
C ₅	100.0	100.0

Plate No.	Temperature (°F)		Vapor Rates (moles/u.t.)	
	W	W/O	W	W/O
1	71.0	75.5	769.0	769.0
2	75.1	81.5	908.5	983.7
3	77.1	82.9	937.1	1073.7
4	78.9	83.0	952.9	1098.6
5	81.4	83.2	962.6	1084.8
6	85.4	84.2	973.9	1060.6
7	89.8	81.0	993.5	1042.6

	No. of Iterations for Solution	Maximum $ T_{k+1} - T_k $ (°F)	IBM 7040 Computing Time (min:sec)
W	50	0.1	15:23
W/O	6	10.3	3:1

Table 11

Comparison of Computing Times for

Example Problem #1

At Various Values of Tolerances

Trial	Wt	THV	VV	BPTV	Iteration	Time	Solution
1	0.1	.0001	.0001	.001	122	2:16	No
2	0.1	.001	.0001	.001	122	2:16	No
3	0.1	.001	.001	.001	30	0:37	Yes
4	0.1	.001	.0001	.0001	82	1:39	Yes
5	0.5	.001	.0001	.001	122	2:17	No

must be carried out. This was done for Example 2. The results of the three trials that were necessary are included as Annex 12 to Appendix F. The time required by three trials of the sum rates and by the bubble point procedure to reach the same result were the same.

The results obtained by sum rates solution of Example 1 using the polynomial data of Hardy et al(14) exactly reproduce the bubble point results of Hardy et al(14). This points out that both methods converge to the unique solution using the convergence criteria presented. This is contrary to the observation of Friday(10) who felt that the bubble point method of Hardy et al(14) did not reach an accurate solution.

The sum rates method was found to fail to converge when the specification of top product was used instead of the specification of the feed temperature. An attempt to include the convergence technique in the sum rates method caused the θ method to fail to converge as well.

In the solution of Example Problem 2, an attempt was made to utilize the control of $|V_{k+1} - V_k|$ as suggested by McNeese(11). In this suggestion to aid convergence, the vapor rate change between iterations must be less than a specified tolerance before the temperature profile is adjusted. In other words, there is a minor iteration to force the vapor profile into convergence within the major temperature iteration loop. This restriction caused a three-fold increase in the computing time required for the problem and did not cause

any change in the solution. From this experience, it appears that the complete iteration for all variables is best left without any interference such as θ forcing, vapor rate iterations or different specifications.

The programs applying the sum rates method to the reboiled absorbers of Problems 6 and 7 have failed to converge to a unique solution. The temperature profiles obtained from successive iterations vary considerably and cause oscillation in the vapor and liquid profiles. Further work on methods of forcing convergence is required in this area.

7.2.3 Evaluation

The sum rates method is the superior method for solution of absorbers in that it

- a) requires considerably less time than the bubble point method to achieve a solution.
- b) can accommodate a change in the location and number of feeds and side stream without reprogramming.

The bubble point method, which works for the reboiled absorber whereas the sum rate does not, is very time consuming, especially when used with Chao Seader data.

7.3 Convergence

As concluded by Napthali(34) there is no criteria by which convergence can be guaranteed for a large system of non-

linear algebraic equations, such as exist for the absorber or reboiled absorber. As illustrated in this work, a change in data can cause non-convergence. For the problems solved on this work the following forcing techniques were used.

a) Bubble Point Method

- 1) Temperature weighting factor
- 2) Theta convergence technique
- 3) constant composition enthalpy balances (with the Yen and Alexander data)
- 4) Restriction of all equilibrium ratios calculated by the Chao Seader correlation so that

$$K \geq .00001 \text{ in all cases.}$$

This was only found necessary in problem No. 3 where the absorber oil reduced temperature went out of correlation limits.

b) Sum Rates Method

- No forcing techniques were required for the absorber solution.

- Attempts to use temperature weighting factors and vapor and liquid profile weighting factors to restrict the change from iteration to iteration did not produce convergence in the case of the reboiled absorber.

c) It was necessary to program a call for the subroutine in the computer system which prevents the program from being stopped because of numbers exceeding the limits of the computer. These limits were exceeded when the ratios (b/d) and (b/d) down were calculated for Problem 7.

8. RECOMMENDATIONS FOR FUTURE WORK

Future work should be directed towards

- a) The evaluation of a matrix solution of the material balance equation such as suggested by Wang and Henke(33) coupled with the sum rates method of solution for a new temperature profile.
- b) Comparing the speed by which bubble point calculations can be completed for the reboiled absorber using the method selected by Wang and Henke(33) and a conventional method. An increase in speed would be most advantageous in the case of the use of the Chao Seader correlation.
- c) The development of an algorithm for use with a specific general correlation which will guarantee convergence for all types of separation problems.

DEFINITION OF SYMBOLS

A	constant in various expressions
AA	dummy variable
AF	absorption factor
AH	enthalpy correlation constant
AK	dummy variable
B	constant in various equations
BB	dummy variable
BH	enthalpy correlation constant
BP	boiling point
b	moles of a component in the bottom product
Cl	composite variable described in equation 3-7d
CH	constant in enthalpy correlation
CJ	dummy variable
d	moles of a component in the top product density
DH	enthalpy correlation constant
E	enthalpy imbalance in BTU
f	moles of a component in the feed stream
FV	moles of vapor in feed
FL	moles of liquid in feed
FEH	feed enthalpy
h	liquid enthalpy dummy variable in the Redlich Kwong equation of state
H	vapor enthalpy

HY	feed vapor enthalpy
HX	feed liquid enthalpy
K	equilibrium ratio (y/x) for a component
l	moles of a component in a liquid stream
L	total moles of liquid in a stream
MW	molecular weight
P	pressure in psia
Q	heat quantity using the convention that heat removed from the column is positive
sp.gr.	specific gravity
S	stripping factor
SSR	specified liquid side stream product rate
T	temperature
v	moles of component in a vapor stream
V	total moles in a vapor stream
Vl	specific volume
w	moles of a component in a side stream
Wl	calculated liquid side stream rate
x	liquid mole fraction of a component
y	vapor mole fraction of a component
Z	compressibility factor
z	total mole fraction of a component in the feed
ZT	dummy variable

Subscripts

top	at the top of the column
bot	at the bottom of the column
down	direction of calculation
c	critical property
ca	cubic average
i	component number
j	plate index
ma	mean average
mla	molal average
n	plate index
NCP	total number of components
NN	bottom plate of the absorber plate above the reboiler in the reboiled absorber
NF1	feed plate number
NQ1	plate number of intercooler/interheater number 1.
NQ2	plate number of intercooler/interheater number 2.
NT	reboiler plate number
MNF1	plate above the feed plate in the reboiled absorber
F	feed stream

Greek Symbols

μ	f/p ratios for the liquid phase
γ	liquid phase activity coefficient
ϕ	vapor phase fugacity coefficient
δ	solubility parameter
θ	convergence forcing factor
ω	acentric factor

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APPENDIX A
DATA

Table 1

Enthalpy Constants for Ideal Gas State

Enthalpy as Determined from Rossini(30) Data

Component	AH(1)	BH(1)	CH(1)	DH(1)
CO ₂	216.013	5042.34	4279.62	-861.623
N ₂	25.6019	6858.14	26.7635	63.2574
CH ₄	124.452	7551.67	-611.562	1919.76
C ₂ H ₆	489.085	4829.65	6722.16	685.048
C ₃ H ₈	725.280	3014.23	14039.0	-540.905
iC ₄	615.743	2761.55	20111.1	-1278.57
nC ₄	749.687	4685.36	17976.8	-721.917
iC ₅	1123.31	2108.48	26463.0	-2502.20
nC ₅	769.671	5657.28	22342.8	-959.097
nC ₆	3119.45	-3165.45	40300.0	-7372.64
nC ₇	-2137.53	19321.6	15081.3	4660.20
nC ₈	3704.27	-3478.07	52312.1	-9206.77
nC ₉	4230.74	-4668.71	59811.8	-10965.4
nC ₁₀	4554.53	-4964.19	66016.9	-12057.8

where

$$H_1^{\circ} = AH_i + BH_i \left(\frac{T}{1000} \right) + CH_i \left(\frac{T}{1000} \right)^2 + DH_i \left(\frac{T}{1000} \right)^3$$

with $T = {}^{\circ}R$

Table 2

Equilibrium and Enthalpy Constants from Hardy et al(14)

Component	a_1	a_2	a_3	a_4
CH ₄	32.718139	- 9.6951405	6.9229334	- 47.361298
C ₂ H ₆	- 9.8400210	67.545943	-37.459290	- 9.0732459
C ₃	-14.512474	53.638924	- 5.3051604	-173.58329
C ₄	-14.181715	36.866353	16.521412	-248.23843
C ₅	- 7.543539	2.0584231	59.138344	-413.12409
C ₈	7.1714400	-52.608530	103.72034	-496.46551

$$(K_i/T)^{1/3} = a_{1i} + a_{2i}T + a_{3i}T^2 + a_{4i}T^3 \quad (T = {}^{\circ}\text{R})$$

Component	AH _i	BH _i x 10	CH _i x 10 ⁵
CH ₄	-17.899210	1.7395763	- 3.7596114
C ₂ H ₆	- 8.4857000	1.6286636	- 1.9498601
C ₃	-14.500060	1.9802223	- 2.9048837
nC ₄	-20.298110	2.3005743	- 3.8663417
nC ₅	-24.371540	2.5636200	- 4.6499694
nC ₈	-22.235050	2.8478429	- 3.8850819

$$(h_i)^{1/2} = \text{AH}_i + \text{BH}_i T + \text{CH}_i T^2 \quad (T = {}^{\circ}\text{R})$$

Component	DH _i	EH _i x 10 ⁴	FH _i x 10 ⁶
CH ₄	44.445874	501.04559	7.3207219
C ₂ H ₆	61.334520	588.75430	11.948654
C ₃	81.795910	389.81919	36.470900
nC ₄	152.66798	-1153.4842	146.64125
nC ₅	128.90152	- 2.0509603	64.501496
nC ₈	106.32806	1328.3949	1.6230737

$$(H_i)^{1/2} = \text{DH}_i + \text{EH}_i T + \text{FH}_i T^2 \quad (T = {}^{\circ}\text{R})$$

APPENDIX A

TABLE 3

CHAO SEADER CONSTANTS FOR THE
CALCULATION OF LIQUID FUGACITY COEFFICIENTS

	GENERAL	METHANE	HYDROGEN
A(1)	0.57574800E 01	0.24384000E 01	0.19671800E 01
A(2)	-0.30176101E 01	-0.22455000E 01	0.10297200E 01
A(3)	-0.49850000E 01	-0.34084000E 00	-0.54008999E-01
A(4)	0.20229900E 01	0.21200000E-02	0.52880000E-03
A(5)	0.	-0.22300000E-02	0.
A(6)	0.84270000E-01	0.10486000E 00	0.85849999E-02
A(7)	0.26667000E 00	-0.36910000E-01	0.
A(8)	-0.31138000E 00	0.	0.
A(9)	-0.26550000E-01	0.	0.
A(10)	0.28830000E-01	0.	0.
A(11)	-0.42389300E 01	0.	0.
A(12)	0.86580800E 01	0.	0.
A(13)	-0.12206000E 01	0.	0.
A(14)	-0.31522400E 01	0.	0.
A(15)	-0.25000000E-01	0.	0.
A(16)	0.	0.	0.

	NITROGEN	CO2	H2S
A(1)	0.27365534E 01	-0.30060874E 02	0.30581210E 01
A(2)	-0.19818310E 01	0.61409853E 01	-0.26491906E 01
A(3)	-0.51487289E 00	0.45263229E 02	0.37457945E 00
A(4)	0.42470988E-01	-0.27303012E 02	-0.14647096E 01
A(5)	-0.28143800E-02	0.59152545E 01	0.45734766E 00
A(6)	-0.29474700E-01	0.36838431E 00	-0.95721679E 00
A(7)	0.21495843E-01	-0.67916811E 00	0.14272648E 01
A(8)	0.	0.15546365E 00	-0.50242238E 00
A(9)	0.	0.	0.33859029E 00
A(10)	0.	0.89562849E-01	-0.26678483E 00
A(11)	0.	0.	0.
A(12)	0.	0.	0.
A(13)	0.	0.	0.
A(14)	0.	0.	0.
A(15)	0.	0.	0.
A(16)	0.	0.	0.

APPENDIX A

TABLE 4

COMPONENT PHYSICAL PROPERTIES
FOR CHAO SEADER CORRELATION

COMPONENTS	TC	PC	W	DELTA	V1
H2S	672.48	1306.5	0.0868	8.800	43.1
NITROGEN	227.16	492.3	0.0206	4.440	53.0
CO2	547.56	1071.3	0.1768	7.120	44.0
METHANE	343.90	673.1	0.0000	5.680	52.0
ETHYLENE	509.50	742.1	0.0949	6.080	61.0
ETHANE	550.50	709.8	0.1064	6.050	68.0
PROPYLENE	657.20	667.0	0.1451	6.430	79.0
PROPANE	665.90	617.4	0.1538	6.400	84.0
I-BUTENE	755.30	583.0	0.2085	6.760	95.3
I-BUTANE	734.70	529.1	0.1825	6.730	105.5
N-BUTANE	765.30	550.7	0.1953	6.730	101.4
I-PENTANE	829.80	483.0	0.2104	7.021	117.4
N-PENTANE	845.60	489.5	0.2387	7.021	116.1
N-HEXANE	914.20	440.0	0.2972	7.266	131.6
N-HEPTANE	972.30	396.8	0.3403	7.430	147.5
N-OCTANE	1024.90	362.1	0.3992	7.551	163.5
N-NONANE	1073.00	332.0	0.4439	7.649	179.6
N-DECANE	1114.00	304.0	0.4869	7.721	196.0

TABLE 5

CHAO SEADER ENTHALPY CONSTANTS

COMPONENTS	AH		BH		CH	DH
H2S	0.3659210E	04	0.8033766E	01	0.6508904E-03	0.3250902E-06
NITROGEN	0.3192124E	04	0.6956438E	01	-0.3103818E-04	0.2350028E-06
CO2	0.3357740E	04	0.8440110E	01	0.3040541E-02	-0.7897689E-06
METHANE	0.3683894E	04	0.7880800E	01	0.3505719E-02	0.2446472E-06
ETHYLENE	0.3791992E	04	0.9144806E	01	0.7819394E-02	-0.1522679E-05
ETHANE	0.4220126E	04	0.1120242E	02	0.8938123E-02	-0.8066164E-06
PROPYLENE	0.4714762E	04	0.1350214E	01	0.1146875E-01	-0.1797251E-05
PROPANE	0.5068633E	04	0.1510799E	02	0.1540639E-01	-0.2938696E-05
I-BUTENE	0.5934714E	04	0.1768871E	01	0.1763632E-01	-0.3901157E-05
I-BUTANE	0.6023067E	04	0.1999786E	02	0.2044134E-01	-0.4146112E-05
N-BUTANE	0.6654675E	04	0.2054464E	02	0.1865250E-01	-0.3016783E-05
I-PENTANE	0.7475643E	04	0.2465428E	02	0.2446248E-01	-0.4437345E-05
N-PENTANE	0.8039759E	04	0.2518989E	02	0.2348587E-01	-0.4174458E-05
N-HEXANE	0.9475028E	04	0.2952267E	02	0.2914070E-01	-0.5911897E-05
N-HEPTANE	0.1056589E	05	0.3331526E	02	0.3278746E-01	-0.6696126E-05
N-OCTANE	0.1226219E	05	0.3899065E	02	0.3841118E-01	-0.7945704E-05
N-NONANE	0.1366069E	05	0.4373618E	02	0.4301726E-01	-0.8954763E-05
N-DECANE	0.1505435E	05	0.4848591E	02	0.4756158E-01	-0.9858597E-05

APPENDIX B
PROGRAMS

C
C
C
C THIS PROGRAM SOLVES ABSORBERS BY THE BUUBLE POINT PROCEDURE
C USING EITHER THE CHAO AND SEADER DATA CORRELATION OR THE
C NGAA AND YEN AND ALEXANDER DATA COMBINATION
C

```

      REAL LO,LOI,LOD1,LOR,LN,LNN,L,LB,LOX
      COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
      COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
      COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
      COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
      COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
      COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
      COMMON EQ(15)
      COMMON PH(15)
      DIMENSION F(15),T(30),TI(30),L(30),V(30),AF(30),S(30)
      DIMENSION ER(15,35),Q(30),LOX(15),BCO(15),CPNT(15,2)
      DIMENSION VD(15,30),LB(15,30),BD(15),TOP(15),BOT(15)
      DIMENSION DCO(15)

```

C
C INPUT/OUTPUT FORMAT STATEMENTS
C

```

100 FORMAT(25I3)
101 FORMAT(8F10.8)
102 FORMAT(10F8.0)
103 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
104 FORMAT(1X,4E14.7)
105 FORMAT(3F10.8,38X,2A6)
110 FORMAT(1H1/1HK,40X,12HPROBLEM NO. ,I2)
111 FORMAT(40X,17HPROBLEM STATEMENT)
112 FORMAT(1HK,43X,8HABSORBER)
113 FORMAT(1HL,17X,15HA. COLUMN DATA)
114 FORMAT(1HJ,27X,15HPRESSURE (PSIA),10X,
116HNUMBER OF PLATES)
116 FORMAT(1HK,19X,21HINTER HEATER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
117 FORMAT(1HJ,31X,F7.1,22X,I2)
118 FORMAT(1HK,19X,21HINTER COOLER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
119 FORMAT(1HL,17X,13HB. FEED DATA)
120 FORMAT(1HJ,37X,19HTEMPERATURE (DEG F),8X,9HCONDITION)
121 FORMAT(20X,4HFEED,17X,13HNOT SPECIFIED,8X,
116HSATURATED VAPOUR)
125 FORMAT(20X,12HABSORBER OIL,12X,F6.1,11X,
117HSUB-COOLED LIQUID)
126 FORMAT(1HK,41X,4HFEED,16X,12HABSORBER OIL)
127 FORMAT(21X,10HCOMPONENTS,4X,8HLB MOLES,5X,4HMOLE,7X,
18HLB MOLES,5X,4HMOLE)
128 FORMAT(35X,8HPER U.T.,3X,8HFRACTION,5X,8HPER U.T.,3X,
18HFRACTION)

```



```

129 FORMAT(20X,2A6,2X,F9.3,3X,F7.4,5X,F9.3,3X,F7.4)
130 FORMAT(1HK,19X,28HSPECIFIED TOP PRODUCT RATE =,F10.3,
114H LB MOLES/U.T.)
132 FORMAT(1HL,17X,17HC. ENTHALPY DATA)
133 FORMAT(1HJ,19X,28HCHAO-SEADER CORRELATION USED)
134 FORMAT(1HJ,19X,34HYEN AND ALEXANDER CORRELATION USED)
135 FORMAT(1HK,32X,32HZERO PRESSURE ENTHALPY CONSTANTS)
136 FORMAT(21X,10HCOMPONENTS,10X,2HAH,9X,2HBH,9X,2HCH,9X,
12HDH)
137 FORMAT(20X,2A6,2X,4E11.4)
138 FORMAT(1HL,17X,26HD. EQUILIBRIUM RATIO DATA)
139 FORMAT(1H1)
140 FORMAT(1HJ,19X,35HNGAA POLYNOMIAL DATA AT CONVERGENCE,
111H PRESSURE =,F7.0,5H PSIA)
141 FORMAT(1HJ,20X,10HCOMPONENTS,6X,2HTC,8X,2HPC,8X,1HW,
17X,5HDELTA,3X,2HV1)
142 FORMAT(20X,2A6,2X,F7.1,3X,F7.1,3X,F7.4,3X,F6.3,F8.2)
143 FORMAT(1HL,17X,23HE. INITIAL ASSUMPTIONS)
144 FORMAT(1HJ,39X,15HPLATE VARIABLES)
145 FORMAT(20X,9HPLATE NO.,5X,11HTEMPERATURE,5X,
111HVAPOUR RATE,5X,11HLIQUID RATE)
146 FORMAT(36X,7H(DEG F),8X,10H(LB MOLES),7X,10H(LB MOLES))
147 FORMAT(51X,10H(PER U.T.),7X,10H(PER U.T.))
148 FORMAT(23X,I2,10X,F7.2,9X,F8.2,8X,F8.2)
149 FORMAT(1HK,39X,15HPRODUCT STREAMS)
150 FORMAT(1HJ,39X,7H DRY GAS,16X,8H RICH OIL)
151 FORMAT(21X,10HCOMPONENTS,7X,10H(LB MOLES),14X,
110H(LB MOLES))
152 FORMAT(38X,10H(PER U.T.),14X,10H(PER U.T.))
153 FORMAT(20X,2A6,6X,F10.3,14X,F10.3)
154 FORMAT(1HJ,19X,11HTOTAL RATES,7X,F10.3,14X,F10.3)
155 FORMAT(1HJ,19X,16HITERATION NUMBER,I4)
157 FORMAT(1HJ,19X,7H THETA =,F9.6)
163 FORMAT(1HJ,19X,29H THETA CONVERGENCE TOLERANCE =,F9.4)
164 FORMAT(1HJ,19X,38HPRODUCT STREAM CONVERGENCE TOLERANCE =,
1F9.4)
165 FORMAT(1HJ,19X,30HTEMPERATURE WEIGHTING FACTOR =,F6.3)
168 FORMAT(1HL,19X,22HNUMBER OF ITERATIONS =,I4)
169 FORMAT(1HJ,19X,29H CALCULATED FEED TEMPERATURE =,F6.1)

```

```

C
C READ IN PROBLEM DATA
C

```

```

ITER=0
READ(5,100) NC,NHC,NN,NQ1,NQ2,KDATA,NOPROB
NT=NN+1
NCP=NC+NHC
READ(5,101) P,TLO,DS,Q1,Q2,PCONV
READ(5,101)(T(N),N=1,NN)
READ(5,101)(L(N),N=1,NN)
READ(5,101)(V(N),N=1,NN)
READ(5,101) VMAX1,VMIN1,THV,VV,WT
IF(KDATA.EQ.1) GO TO 20

```



```

      READ(5,100) JH2,JC1,JN2,J02,JCO,JCO2,JH2S
      READ(5,101)((A(I,J),I=1,16),J=1,6)
      DO 26 I=1,NC
      READ(5,103) TC(I),PC(I),W(I),DELTA(I),V1(I),(CPNT(I,J)
1,J=1,2)
      READ(5,101) ZM(I),LO(I)
26 READ(5,104) AH(I),BH(I),CH(I),DH(I)
      IF(NCP.LE.NC) GO TO 27
      CALL PHYS(CPNT)
      GO TO 27
20 DO 19 I=1,NCP
      READ(5,105) ZC(I),TC(I),PC(I),(CPNT(I,J),J=1,2)
      READ(5,101) ZM(I),LO(I)
19 READ(5,101) AH(I),BH(I),CH(I),DH(I),EH(I),FH(I)
      IF(KDATA.EQ.2) GO TO 27
      CALL PHYS(CPNT)
27 MNN=NN-1

```

```

C
C  CALCULATE MOLE FRACTIONS IN FEED STREAMS
C

```

```

      FR=0.
      LOR=0.
      DO 23 I=1,NCP
      F(I)=ZM(I)
      FR=FR+F(I)
23 LOR=LOR+LO(I)
      V(1)=DS
      L(NN)=LOR+FR-DS
      DO 16 I=1,NCP
      J=NT+2
      ZF(I)=F(I)/FR
      XT(I,J)=ZF(I)
      LOX(I)=LO(I)/LOR
      J=NT+1
16 XT(I,J)=LOX(I)

```

```

C
C  PRINT OUT PROBLEM STATEMENT
C

```

```

      WRITE(6,110) NOPROB
      WRITE(6,111)
      WRITE(6,112)
      WRITE(6,113)
      WRITE(6,114)
      WRITE(6,117) P,NN
      IF(NQ1.GT.NN) GO TO 66
      IF(Q1.LT.0.) GO TO 63
      WRITE(6,118) NQ1,Q1
      GO TO 66
63 WRITE(6,116) NQ1,Q1
66 IF(NQ2.GT.NN) GO TO 62
      IF(Q2.LT.0.) GO TO 65
      WRITE(6,118) NQ2,Q2

```



```

        GO TO 62
65 WRITE(6,116) NQ2,Q2
62 WRITE(6,163) THV
   WRITE(6,164)VV
   WRITE(6,165) WT
   WRITE(6,119)
   WRITE(6,120)
   WRITE(6,121)
   WRITE(6,125) TLO
   WRITE(6,126)
   WRITE(6,127)
   WRITE(6,128)
   DO 69 I=1,NCP
   WRITE(6,129)(CPNT(I,J),J=1,2),ZM(I),ZF(I),LO(I),LOX(I)
69 CONTINUE
   WRITE(6,130) DS
   WRITE(6,139)
   WRITE(6,132)
   IF(KDATA.EQ.1) GO TO 67
   WRITE(6,133)
   GO TO 68
67 WRITE(6,134)
68 WRITE(6,138)
   IF(KDATA.EQ.1) GO TO 73
   WRITE(6,133)
   GO TO 74
73 WRITE(6,140) PCONV
74 WRITE(6,143)
   WRITE(6,144)
   WRITE(6,145)
   WRITE(6,146)
   WRITE(6,147)
   DO 72 N=1,NN
   WRITE(6,148)N,T(N),V(N),L(N)
72 CONTINUE
   WRITE(6,139)

```

```

C
C   BEGIN SOLUTION OF PROBLEM
C

```

```

50 ITER=ITER+1
   WRITE(6,155) ITER
   BOTS=0.
   TOPS=0.
   KENTH=5
   DO 30 N=1,NN
   IF(KDATA.EQ.1) GO TO 14
   IF(ITER.LT.2) GO TO 28
   DO 32 I=1,NCP
   XT(I,N)=X(I,N)
32 YT(I,N)=Y(I,N)
14 CALL K(T(N),KENTH,N)
   GO TO 31

```



```

28 CALL KIDL(T(N))
31 DO 30 I=1,NCP
30 ER(I,N)=EQ(I)
    DO 2 I=1,NCP
    DO 25 N=1,NN
    AF(N)=L(N)/(ER(I,N)*V(N))
25 S(N)=1./AF(N)
    LOI=LO(I)
    FI=F(I)

```

```

C
C CALCULATE B/D RATIOS DOWN THE COLUMN
C

```

```

    AA=AF(1)
    BB=1.
    DO 1 N=3,NT
    AFI=AF(N-1)
    AA=AA*AFI
1 BB=BB*AFI+1.
    BDDOWN=(AA*LOI+FI*(AA+BB-1.))/(FI+BB*LOI)
    DDOWN=(LOI+FI)/(1.+BDDOWN)
    BDOWN=BDDOWN*DDOWN

```

```

C
C CALCULATE B/D RATIOS UP THE COLUMN
C

```

```

    AA=1.
    BB=0.
    DO 29 N=1,NN
    J=NN+1-N
    SF=S(J)
    AA=AA*SF
29 BB=BB*SF+1.
    ZT=LOI+FI
    AK=LOI+BB*FI
    BDUP=AK/((AA+BB)*ZT-AK)
    BUP=ZT/(1.+1.0/BDUP)
    DUP=BUP/BDUP

```

```

C
C CALCULATE V/D FOR EACH PLATE
C

```

```

    LOD1=1.-LOI/DDOWN
    VD(I,1)=1.
    DO 3 N=2,NN
3 VD(I,N)=AF(N-1)*VD(I,N-1)+LOD1

```

```

C
C CALCULATE L/B FOR EACH PLATE
C

```

```

    F1B=1.-FI/BUP
    LB(I,NN)=1.
    DO 4 N=1,MNN
    J=1+NN-N
4 LB(I,J-1)=LB(I,J)*S(J)+F1B

```

```

C

```


C CALCULATE ROUND-OFF ERROR RATIOS

C

```
BDTOP=1./(LB(I,1)*S(1))
BDBOT=VD(I,NN)*AF(NN)
RTOP=BDTOP/BDUP
RBOT=BDBOT/BDDOWN
IF(ABS(RTOP-1.0).LE.ABS(RBOT-1.0)) GO TO 5
BD(I)=BDDOWN
TOP(I)=DDOWN
BOT(I)=BDOWN
DO 7 N=1,NN
7 LB(I,N)=VD(I,N)*AF(N)/BD(I)
GO TO 24
5 BD(I)=BDUP
TOP(I)=DUP
BOT(I)=BUP
DO 6 N=1,NN
6 VD(I,N)=LB(I,N)*S(N)*BD(I)
24 TOPS=TOPS+TOP(I)
BOTS=BOTS+BOT(I)
2 CONTINUE
```

C

C CHECK CONVERGENCE CRITERIA

C

```
IF(ABS(TOPS-DS).GT.VV) GO TO 35
IF(ABS(TH-1.0).GT.THV) GO TO 35
DO 33 N=1,NN
IF(ABS(TI(N)-T(N)).GT.0.1) GO TO 35
33 CONTINUE
GO TO 51
```

C

C THETA CONVERGENCE PROCEDURE

C

```
35 TH=0.9
9 G1=0.
DCOSM=0.
DO 8 I=1,NCP
DCO(I)=(F(I)+LO(I))/(1.+TH*BD(I))
BCO(I)=TH*BD(I)*DCO(I)
G1=G1+(BD(I)*(F(I)+LO(I)))/((1.+TH*BD(I))**2)
8 DCOSM=DCOSM+DCO(I)
G=DCOSM-DS
IF(ABS(G).LT. THV) GO TO 10
THN=TH+G/G1
IF(THN.LT.0.) THN=TH/2.
TH=THN
GO TO 9
```

C

C CALCULATE NEW MOLE FRACTIONS ON EACH PLATE

C

```
10 DO 11 N=1,NN
SV=0.
```



```

      SL=0.
      DO 12 I=1,NCP
      SV=SV+VD(I,N)*DCO(I)
12  SL=SL+LB(I,N)*BCO(I)
      DO 11 I=1,NCP
      X(I,N)=LB(I,N)*BCO(I)/SL
      Y(I,N)=VD(I,N)*DCO(I)/SV
      XT(I,N)=X(I,N)
      YT(I,N)=Y(I,N)
11  CONTINUE

```

```

C
C  CALCULATE NEW TEMPERATURE PROFILE BY BUBBLE POINT
C

```

```

      DO 13 N=1,NN
      Q(N)=0.
      TI(N)=T(N)
      TN=T(N)
      CALL BUBPT(TN,XT,N)
15  T(N)=TI(N)+WT*(TN-TI(N))
13  CONTINUE

```

```

C
C  ENTHALPY BALANCES
C

```

```

      Q(NQ1)=Q1
      Q(NQ2)=Q2
      SQC=0.
      N=1
      KENTH=2
      CALL ENTHAL(T(N),Y,KENTH,N)
      HV1=ENTH*V(1)
      KENTH=4
      J=NT+1
      CALL ENTHAL(TLO,XT,KENTH,J)
      HAB=ENTH*LOR
      N=NN
      KENTH=3
      CALL ENTHAL(T(N),X,KENTH,N)
      HB=ENTH*L(NN)
      DO 18 N=2,NN
      SQC=SQC+Q(N-1)
      KENTH=3
      CALL ENTHAL(T(N-1),X,KENTH,N-1)
      HTL=ENTH
      IF(KDATA.EQ.1) GO TO 21

```

```

C
C  CONVENTIONAL ENTHALPY BALANCES
C

```

```

      KENTH=2
      CALL ENTHAL(T(N),Y,KENTH,N)
      HTV=ENTH
      DEN=HTV-HTL
      VN=(HV1-HAB+(LOR-V(1))*HTL+SQC)/DEN

```



```

LN=LOR+V(N)-V(1)
IF(VN.LT.0.) VN=V(N)/2.
IF(LN.LT.0.) LN=L(N-1)/2.
V(N)=VN
LN=LOR+V(N)-V(1)
LNN=LN
QC=0.
GO TO 22

```

```

C
C  CONSTANT COMPOSITION ENTHALPY BALANCES
C

```

```

21 KENTH=5
   CALL ENTHAL(T(N),YT,KENTH,N)
   HPAB=0.
   HPV1=0.
   HPL=0.
   DO 17 I=1,NCP
     HPAB=HPAB+PH(I)*LOX(I)
     HPV1=HPV1+PH(I)*Y(I,1)
17  HPL=HPL+PH(I)*X(I,N-1)
     DEN=HPL-HTL
     LN=(LOR*HPAB-HAB+HV1-V(1)*HPV1+SQC)/DEN
     V(N)=V(1)+LN-LOR
     LNN=LN

```

```

C
C  Q METHOD ENTHALPY BALANCE SECTION
C

```

```

22 IF(V(N).GT.VMAX1) V(N)=VMAX1
   IF(V(N).LT.VMIN1) V(N)=VMIN1
   LNN=LOR+V(N)-V(1)
   L(N-1)=LNN
   QC=LNN*DEN-LN*DEN
   SQC=SQC+QC
18  CONTINUE
   HF=HV1+HB-HAB+SQC

```

```

C
C  TRIAL AND ERROR SOLUTION FOR FEED TEMPERATURE
C

```

```

   TF=T(NN)
   N=NT+2
   CALL TRIAL(TF,HF,N)
   GO TO 50

```

```

C
C  OUTPUT ANSWERS
C
C

```

```

51 CONTINUE
   WRITE(6,110) NOPROB
   WRITE(6,149)
   WRITE(6,150)
   WRITE(6,151)
   WRITE(6,152)

```



```
DO 34 I=1,NCP
WRITE(6,153)(CPNT(I,J),J=1,2),TOP(I),BOT(I)
34 CONTINUE
WRITE(6,154) TOPS,BOTS
WRITE(6,144)
WRITE(6,145)
WRITE(6,146)
WRITE(6,147)
DO 77 N=1,NN
WRITE(6,148) N,T(N),V(N),L(N)
77 CONTINUE
WRITE(6,169) TF
WRITE(6,157) TH
WRITE(6,168) ITER
CALL EXIT
END
```


C
C
C
C
C


```

113HVAPOUR/LIQUID)
125 FORMAT(20X,12HABSORBER OIL,12X,F6.1,11X,
117HSUB-COOLED LIQUID)
126 FORMAT(1HK,41X,4HFEED,16X,12HABSORBER OIL)
127 FORMAT(21X,10HCOMPONENTS,4X,8HLB MOLES,5X,4HMOLE,7X,
18HLB MOLES,5X,4HMOLE)
128 FORMAT(35X,8HPER U.T.,3X,8HFRACTION,5X,8HPER U.T.,3X,
18HFRACTION)
129 FORMAT(20X,2A6,2X,F9.3,3X,F7.4,5X,F9.3,3X,F7.4)
130 FORMAT(1HK,19X,26HSPECIFIED TOP PRODUCT RATE,5X,
126HSPECIFIED SIDE STREAM RATE)
131 FORMAT(1HJ,21X,F9.3,14H LB MOLES/U.T.,7X,F9.3,
114H LB MOLES/U.T.)
132 FORMAT(1HL,17X,17HC. ENTHALPY DATA)
133 FORMAT(1HJ,19X,28HCHAO-SEADER CORRELATION USED)
134 FORMAT(1HJ,19X,34HYEN AND ALEXANDER CORRELATION USED)
135 FORMAT(1HK,32X,32HZERO PRESSURE ENTHALPY CONSTANTS)
136 FORMAT(21X,10HCOMPONENTS,10X,2HAH,9X,2HBH,9X,2HCH,9X,
12HDH)
137 FORMAT(20X,2A6,2X,4E11.4)
138 FORMAT(1HL,17X,26HD. EQUILIBRIUM RATIO DATA)
139 FORMAT(1H1)
140 FORMAT(1HJ,19X,35HNGAA POLYNOMIAL DATA AT CONVERGENCE,
111H PRESSURE =,F7.0,5H PSIA)
141 FORMAT(1HJ,20X,10HCOMPONENTS,6X,2HTC,8X,2HPC,8X,1HW,
17X,5HDELTA,3X,2HVI)
142 FORMAT(20X,2A6,2X,F7.1,3X,F7.1,3X,F7.4,3X,F6.3,F8.2)
143 FORMAT(1HL,17X,23HE. INITIAL ASSUMPTIONS)
144 FORMAT(1HJ,39X,15HPLATE VARIABLES)
145 FORMAT(20X,9HPLATE NO.,5X,11HTEMPERATURE,5X,
111HVAPOUR RATE,5X,11HLIQUID RATE)
146 FORMAT(36X,7H(DEG F),8X,10H(LB MOLES),6X,10H(LB MOLES))
147 FORMAT(51X,10H(PER U.T.),6X,10H(PER U.T.))
148 FORMAT(23X,12,10X,F7.2,9X,F8.2,8X,F8.2)
149 FORMAT(1HK,39X,15HPRODUCT STREAMS)
150 FORMAT(1HJ,34X,27HTOP PRODUCT BOTTOM PRODUCT,3X,
111HSIDE STREAM)
151 FORMAT(21X,10HCOMPONENTS,4X,10H(LB MOLES),5X,
110H(LB MOLES),5X,10H(LB MOLES))
152 FORMAT(35X,10H(PER U.T.),5X,10H(PER U.T.),5X,
110H(PER U.T.))
153 FORMAT(20X,2A6,4X,F9.3,6X,F9.3,6X,F9.3)
154 FORMAT(1HJ,19X,11HTOTAL RATES,5X,F9.3,6X,F9.3,6X,F9.3)
155 FORMAT(1HJ,19X,16HITERATION NUMBER,I4)
156 FORMAT(1HL)
157 FORMAT(1HJ,19X,6HTHETA(,I2,3H) =,F9.6)
158 FORMAT(1HJ,19X,38HMAXIMUM VAPOUR RATE ABOVE FEED PLATE =,
1F9.3)
159 FORMAT(1HJ,19X,38HMAXIMUM VAPOUR RATE BELOW FEED PLATE =,
1F9.3)
160 FORMAT(1HJ,19X,38HMINIMUM VAPOUR RATE ABOVE FEED PLATE =,
1F9.3)

```



```

162 FORMAT(1HJ,19X,38HMINIMUM VAPOUR RATE BELOW FEED PLATE =,
1F9.3)
163 FORMAT(1HJ,19X,29HTHETA CONVERGENCE TOLERANCE =,F9.4)
164 FORMAT(1HJ,19X,38HPRODUCT STREAM CONVERGENCE TOLERANCE =,
1F9.4)
165 FORMAT(1HJ,19X,30HTEMPERATURE WEIGHTING FACTOR =,F6.3)
166 FORMAT(1HK,19X,21HINTER COOLER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
167 FORMAT(1HK,19X,21HINTER HEATER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
168 FORMAT(1HL,19X,22HNUMBER OF ITERATIONS =,I4)
169 FORMAT(1HJ,19X,26HCALCULATED REBOILER LOAD =,E16.8,
19H BTU/U.T.)

```

C
C
C

READ IN DATA

```

ITER=0
READ(5,100) NC,NHC,NN,NF1,NQ1,NQ2,FC,KDATA,NOPROB
NCP=NC+NHC
NNF1=NF1+1
MNF1=NF1-1
NT=NN+1
READ(5,101) TOPPR,SSR,P,FT,TLO,Q1,Q2,PCONV
READ(5,101) (T(N),N=1,NT)
READ(5,101) (L(N),N=1,NT)
READ(5,101) (V(N),N=1,NT)
READ(5,101) VMAX1,VMAX2,VMIN1,VMIN2,THV,VV,WT
IF(KDATA.EQ.1) GO TO 3
READ(5,100) JH2,JC1,JN2,JO2,JCO,JCO2,JH2S
READ(5,101)((A(I,J),I=1,16),J=1,6)
DO 1 I=1,NC
READ(5,103) TC(I),PC(I),W(I),DELTA(I),V1(I),(CPNT(I,J),J=1,2)
READ(5,101) ZM(I),LO(I)
1 READ(5,104) AH(I),BH(I),CH(I),DH(I)
IF(NCP.LE.NC) GO TO 2
CALL PHYS(CPNT)
GO TO 2
3 DO 4 I=1,NCP
READ(5,105) ZC(I),TC(I),PC(I),(CPNT(I,J),J=1,2)
READ(5,101) ZM(I),LO(I)
4 READ(5,101) AH(I),BH(I),CH(I),DH(I),EH(I),FH(I)
CALL PHYS(CPNT)

```

C
C
C

CALCULATE MOLE FRACTIONS IN FEED STREAMS

```

2 FR=0.
LOR=0.
DO 5 I=1,NCP
FR=FR+ZM(I)
5 LOR=LOR+LO(I)
V(1)=TOPPR
L(NT)=FR+LOR-TOPPR-SSR

```



```

DO 6 I=1,NCP
ZF(I)=ZM(I)/FR
LOX(I)=LO(I)/LOR
N=NT+3
XT(I,N)=LOX(I)
N=NT+2
6 XT(I,N)=ZF(I)

```

```

C
C CALCULATE FEED ENTHALPIES AND CONDITIONS OF FEED
C

```

```

KENTH=4
N=NT+3
CALL ENTHAL(TLO,XT,KENTH,N)
HAB=ENTH*LOR
N=NT+1
IF(FC.EQ.2) GO TO 8
IF(FC.EQ.3) GO TO 7
IF(FC.EQ.4) GO TO 7

```

```

C
C FLASH FEED
C

```

```

CALL FLASH(FT,N)
DO 9 I=1,NCP
XT(I,N)=XF(I)
9 YT(I,N)=YF(I)
KENTH=3
CALL ENTHAL(FT,XT,KENTH,N)
HX=ENTH
KENTH=2
CALL ENTHAL(FT,YT,KENTH,N)
HY=ENTH
GO TO 10

```

```

C
C BUBBLE POINT FEED
C

```

```

7 FL=FR
FV=0.
DO 11 I=1,NCP
XM(I)=ZM(I)
YM(I)=0.
XF(I)=ZF(I)
YF(I)=0.
XT(I,N)=XF(I)
11 YT(I,N)=YF(I)
CALL BUBPT(FT,XT,N)
KENTH=3
CALL ENTHAL(FT,XT,KENTH,N)
HX=ENTH
HY=0.
GO TO 10

```

```

C
C DEW POINT FEED

```


C

```
8 FL=0.
  FV=FR
  DO 12 I=1,NCP
    XM(I)=0.
    YM(I)=ZM(I)
    XF(I)=0.
    YF(I)=ZF(I)
    XT(I,N)=XF(I)
12 YT(I,N)=YF(I)
  CALL DEWPT(FT,YT,N)
  KENTH=2
  CALL ENTHAL(FT,YT,KENTH,N)
  HY=ENTH
  HX=0.
10 HF=(FV*HY+FL*HX)/FR
  SHF=SHF+FR*HF
  DO 13 N=1,NT
    LFD(N)=0.
    VFB(N)=0.
    VF(N)=0.
13 LF(N)=0.
  N=NF1
  VF(N)=FV
  LF(N)=FL
```

C

C

C

PRINT OUT PROBLEM STATEMENT

```
  WRITE(6,110) NOPROB
  WRITE(6,111)
  WRITE(6,112)
  WRITE(6,113)
  WRITE(6,114)
  WRITE(6,115)
  WRITE(6,116)
  IF(SSR.LT.0.20E-10) GO TO 65
  WRITE(6,117) P,NT,NF1,NN
  GO TO 66
65 WRITE(6,118) P,NT,NF1
66 WRITE(6,130)
  WRITE(6,131) TOPPR,SSR
  IF(NQ1.GT.NT) GO TO 80
  IF(Q1.LT.0.) GO TO 81
  WRITE(6,166) NQ1,Q1
  GO TO 80
81 WRITE(6,167) NQ1,Q1
80 IF(NQ2.GT.NT) GO TO 82
  IF(Q2.LT.0.) GO TO 83
  WRITE(6,166) NQ2,Q2
  GO TO 82
83 WRITE(6,167) NQ2,Q2
82 IF(VMIN1.LT.0.00001) GO TO 84
```



```

WRITE(6,158) VMAX1
WRITE(6,160) VMIN1
WRITE(6,159) VMAX2
WRITE(6,162) VMIN2
84 WRITE(6,163) THV
WRITE(6,164) VV
WRITE(6,165) WT
WRITE(6,119)
WRITE(6,120)
J=1
IF(FC.EQ.2) GO TO 60
IF(FC.EQ.3) GO TO 62
IF(FC.EQ.4) GO TO 61
IF(FC.EQ.5) GO TO 63
GO TO 64
60 WRITE(6,121) J,FT
GO TO 64
61 WRITE(6,122) J,FT
GO TO 64
62 WRITE(6,123) J,FT
GO TO 64
63 WRITE(6,124) J,FT
64 WRITE(6,125) TLO
WRITE(6,126)
WRITE(6,127)
WRITE(6,128)
DO 69 I=1,NCP
WRITE(6,129)(CPNT(I,J),J=1,2),ZM(I),ZF(I),LO(I),LOX(I)
69 CONTINUE
WRITE(6,139)
WRITE(6,132)
IF(KDATA.EQ.1) GO TO 67
WRITE(6,133)
GO TO 68
67 WRITE(6,134)
68 WRITE(6,138)
IF(KDATA.EQ.1) GO TO 73
WRITE(6,133)
GO TO 74
73 WRITE(6,140) PCONV
74 WRITE(6,143)
WRITE(6,144)
WRITE(6,145)
WRITE(6,146)
WRITE(6,147)
DO 72 N=1,NT
WRITE(6,148)N,T(N),V(N),L(N)
72 CONTINUE
WRITE(6,139)

```

```

C
C BEGIN ITERATION
C

```



```

51 ITER=ITER+1
   WRITE(6,155) ITER
   KENTH=5
   DO 15 N=1,NT
     IF(KDATA.EQ.1) GO TO 20
     IF(ITER.LT.2) GO TO 14
     DO 75 I=1,NCP
       XT(I,N)=X(I,N)
75  YT(I,N)=Y(I,N)
20  CALL K(T(N),KENTH,N)
     GO TO 46
14  CALL KIDL(T(N))
46  DO 15 I=1,NCP
15  ER(I,N)=EQ(I)
     W1=0.
     TOPS=0.
     BOTS=0.
     CALL FPTSW
     DO 30 I=1,NCP
     DO 19 N=1,NT
       AF(N)=L(N)/(ER(I,N)*V(N))
19  S(N)=1./AF(N)
     LOI=LO(I)

```

C
C
C

CALCULATE B/D RATIOS UP THE COLUMN

```

   AA=1.
   BB=0.
   DD=1.
   EE=1.
   DO 17 N=1,NT
     J=1+NT-N
     SF=S(J)
     IF(J.GT.MNF1) GO TO 18
     EE=EE*SF
     DD=DD*SF+1.
18  BB=BB*SF+1.
     AA=AA*SF
17  CONTINUE
     ZT=LOI+DD*ZM(I)-EE*YM(I)
     C1=1.+SSR*(S(NT)+1.)/(L(NN)-SSR)
     BDUP=ZT/((AA+BB*C1)*(LOI+ZM(I))-(C1*ZT))
     BUP=(LOI+ZM(I))/(C1+1./BDUP)
     DUP=BUP/BDUP

```

C
C
C

CALCULATE B/D RATIOS DOWN THE COLUMN AND L/B

```

   AA=AF(1)
   BB=1.
   DO 21 N=3,NF1
     AFI=AF(N-1)
     AA=AA*AFI

```



```

21 BB=BB*AFI+1.
   VFB(MNF1)=YM(I)/BUP
   ZB=0.
   LB(I,NT)=1.
   NX=NN-1
   LB(I,NN)=L(NN)*(S(NT)+1.)/(L(NN)-SSR)
   DO 23 N=1,NX
     J=1+NX-N
     IF(J.EQ.MNF1) ZB=ZM(I)/BUP
23 LB(I,J)=LB(I,J+1)*S(J+1)+C1+VFB(J)-ZB
   VBNF1=LB(I,NF1)*S(NF1)
   AK=AA+BB
   CJ=XM(I)-ZM(I)-BB*LOI
   ZT=ZM(I)+LOI
   WB=C1-1.
   WDT=1.+WB*BDUP
   BDDOWN=(AK*ZT+CJ*WDT)/(VBNF1*ZT-CJ)
   DDOWN=ZT/(BDDOWN+WDT)
   BDOWN=BDDOWN*DDOWN

```

C
C
C

CALCULATE V/D

```

   LOD1=1.-LOI/DDOWN
   ZD=0.
   LFD(NF1)=XM(I)/DDOWN
   VD(I,1)=1.
   DO 24 N=2,NT
     IF(N.EQ.NF1) ZD=ZM(I)/DDOWN
24 VD(I,N)=VD(I,N-1)*AF(N-1)+LOD1+LFD(N)-ZD

```

C
C
C

CALCULATE ROUND-OFF ERROR RATIOS

```

   BDTOP=1./(S(1)*LB(I,1))
   BDNF1=AF(NF1)*VD(I,NF1)/LB(I,NF1)
   RTOP=BDTOP/BDUP
   RNF1=BDNF1/BDDOWN
   IF(ABS(RTOP-1.).LE.ABS(RNF1-1.)) GO TO 28
   BD(I)=BDDOWN
   TOP(I)=DDOWN
   BOT(I)=BDOWN
   DO 25 N=1,NF1
25 LB(I,N)=VD(I,N)*AF(N)/BD(I)
   DO 26 N=NNF1,NT
26 VD(I,N)=LB(I,N)*S(N)*BD(I)
   GO TO 29
28 BD(I)=BDUP
   TOP(I)=DUP
   BOT(I)=BUP
   DO 27 N=1,NT
27 VD(I,N)=LB(I,N)*S(N)*BD(I)
29 WD(I)=AF(NN)*VD(I,NN)*SSR/L(NN)
   WW(I)=WD(I)*TOP(I)

```



```

      W1=W1+WW(I)
      BOTS=BOTS+ROT(I)
30  TOPS=TOPS+TOP(I)
      CALL FPTSW

```

C
C CHECK CONVERGENCE CRITERIA
C

```

      IF(ABS(TOPPR-TOPS).GT.VV) GO TO 40
      IF(ABS(W1-SSR).GT.VV) GO TO 40
      IF(ABS(TH(2)-1.0).GT.THV) GO TO 40
      IF(ABS(TH(1)-1.0).GT.THV) GO TO 40
      DO 55 N=1,NT
      IF(ABS(TI(N)-T(N)).GT.0.1) GO TO 40
55  CONTINUE
      GO TO 50

```

C
C THETA CONVERGENCE PROCEDURE
C

```

40  DO 31 J=1,2
31  TH(J)=1.
32  DO 33 J=1,2
      GT(J)=0.
      DO 33 M=1,2
33  GP(J,M)=0.
      CALL FPTSW
      DO 34 I=1,NCP
      ZFT=ZM(I)+LO(I)
      DCO(I)=ZFT/(1.+TH(1)*BD(I)+TH(2)*WD(I))
      DEN=DCO(I)/ZFT*DCO(I)
      BCO(I)=TH(1)*BD(I)*DCO(I)
      GP(1,1)=GP(1,1)-BD(I)*DEN
      GT(1)=GT(1)+DCO(I)
      IF(SSR.LT.0.10E-10) GO TO 34
      WCO(I)=TH(2)*WD(I)*DCO(I)
      GP(1,2)=GP(1,2)-WD(I)*DEN
      GP(2,1)=GP(2,1)-BD(I)*DEN*TH(2)*WD(I)
      GP(2,2)=GP(2,2)+DEN*WD(I)*((ZFT/DCO(I))-WD(I)*TH(2))
      GT(2)=GT(2)+WCO(I)
34  CONTINUE
      CALL FPTSW
      G(1)=TOPPR-GT(1)
      G(2)=SSR-GT(2)
      IF(ABS(G(1)).GT.TOPPR*0.0001) GO TO 36
      IF(ABS(G(2)).GT.TOPPR*0.0001) GO TO 36
      GO TO 35
36  IF(SSR.LT.0.10E-30) GO TO 47
      ANUM=(G(1)/GP(1,1))-(G(2)/GP(2,1))
      ADEN=(GP(1,2)/GP(1,1))-GP(2,2)/GP(2,1)
      DTH(2)=ANUM/ADEN
      DTH(1)=(G(1)-DTH(2)*GP(1,2))/GP(1,1)
48  DO 37 J=1,2
      THN(J)=TH(J)+DTH(J)

```



```

      IF (THN(J).LT.0.) THN(J)=TH(J)/2.
37 TH(J)=THN(J)
   GO TO 32
47 DTH(1)=G(1)/GP(1,1)
   DTH(2)=0.
   GO TO 48

```

```

C
C   CALCULATE NEW MOLE FRACTIONS ON EACH PLATE
C

```

```

35 DO 38 N=1,NT
   VT(N)=0.
   LT(N)=0.
   DO 39 I=1,NCP
      VT(N)=VD(I,N)*DCO(I)+VT(N)
39 LT(N)=LT(N)+LB(I,N)*BCO(I)
   DO 38 I=1,NCP
      X(I,N)=LB(I,N)*BCO(I)/LT(N)
38 Y(I,N)=VD(I,N)*DCO(I)/VT(N)

```

```

C
C   CALCULATE NEW TEMPERATURE PROFILE BY BUBBLEPOINT
C

```

```

   DO 41 N=1,NT
      Q(N)=0.
      TI(N)=T(N)
      TN=T(N)
      CALL BUBPT(TN,X,N)
      T(N)=TI(N)+WT*(TN-TI(N))
41 CONTINUE

```

```

C
C   ENTHALPY BALANCES
C

```

```

   Q(NQ1)=Q1
   Q(NQ2)=Q2
   SQC=0.
   SFR=0.
   N=1
   KENTH=2
   CALL ENTHAL(T(N),Y,KENTH,N)
   HV1=ENTH*V(1)
   N=NT
   KENTH=3
   CALL ENTHAL(T(N),X,KENTH,N)
   HB=ENTH*L(NT)
   N=NN
   KENTH=3
   CALL ENTHAL(T(N),X,KENTH,N)
   HW1=ENTH*SSR
   DO 42 N=2,NT
      SFR=SFR+VF(N)+LF(N-1)
      SQC=SQC+Q(N-1)
      KENTH=3
      CALL ENTHAL(T(N-1),X,KENTH,N-1)

```



```
HTL=ENTH
IF(KDATA.EQ.1) GO TO 49
```

```
C
C CONVENTIONAL ENTHALPY BALANCES
```

```
C
KENTH=2
CALL ENTHAL(T(N),Y,KENTH,N)
HTV=ENTH
DEN=HTV-HTL
VN=(HV1-HAB+(LOR-V(1))*HTL+SQC)/DEN
IF(N.LT.NF1) GO TO 53
VN=VN-FV*(HTL-HY)/DEN
IF(N.LT.NNF1) GO TO 53
VN=VN+(FV*(HTL-HY)+FR*(HTL-HF))/DEN
53 CONTINUE
IF(VN.LT.0.) VN=V(N)/2.
V(N)=VN
QC=0.
LN=V(N)+LOR+SFR-V(1)
GO TO 54
```

```
C
C CONSTANT COMPOSITION ENTHALPY BALANCES
```

```
C
49 KENTH=5
CALL ENTHAL(T(N),Y,KENTH,N)
HPYF=0.
HPF=0.
HPV1=0.
HPAB=0.
HPL=0.
DO 70 I=1,NCP
HPYF=HPYF+PH(I)*YF(I)
HPF=HPF+PH(I)*ZF(I)
HPV1=HPV1+PH(I)*Y(I,1)
HPAB=HPAB+PH(I)*LOX(I)
70 HPL=HPL+PH(I)*X(I,N-1)
DEN=HPL-HTL
LN=(LOR*HPAB-HAB+HV1-V(1)*HPV1+SQC)/DEN
IF(N.LT.NF1) GO TO 43
VFDH=VF(N)*(HPYF-HY)/DEN
LN=LN+VFDH
IF(N.LT.NNF1) GO TO 43
LN=LN+FR*(HPF-HF)/DEN-VFDH
43 CONTINUE
QC=0.
LNN=LN
V(N)=V(1)+LNN-LOR-SFR
```

```
C
C Q METHOD ENTHALPY BALANCE SECTION
```

```
C
54 IF(N.LT.NF1) GO TO 44
IF(V(N).GT.VMAX2) V(N)=VMAX2
```



```

        IF(V(N).LT.VMIN2) V(N)=VMIN2
        GO TO 45
44  IF(V(N).GT.VMAX1) V(N)=VMAX1
        IF(V(N).LT.VMIN1) V(N)=VMIN1
45  LNN=V(N)-V(1)+LOR+SFR
        IF(LNN.LT.0.) LNN=L(N-1)/2.
        L(N-1)=LNN
        NX=N-1
        QC=LNN*DEN-LN*DEN
42  SQC=SQC+QC
        QR=HV1+HB+HW1-SHF-HAB+SQC
        GO TO 51

```

```

C
C  OUTPUT ANSWERS
C

```

```

50  CONTINUE
    WRITE(6,110) NOPROB
    WRITE(6,149)
    WRITE(6,150)
    WRITE(6,151)
    WRITE(6,152)
    DO 76 I=1,NCP
        WRITE(6,153)(CPNT(I,J),J=1,2),TOP(I),BOT(I),WW(I)
76  CONTINUE
    WRITE(6,154) TOPS,BOTS,W1
    WRITE(6,144)
    WRITE(6,145)
    WRITE(6,146)
    WRITE(6,147)
    DO 77 N=1,NT
77  WRITE(6,148) N,T(N),V(N),L(N)
        WRITE(6,169) QR
        DO 78 J=1,2
78  WRITE(6,157) J,TH(J)
        WRITE(6,168) ITER
        CALL EXIT
    END

```


ABSORBER PROGRAM USING THE SUM RATES PROCEDURE WITH CHAO AND SEADER DATA

```

REAL LO,LOI,LOD1,LOT,LN,LNN,L,LB,K,KCONST
REAL LOX,LT
COMMON NC,NHC,NCP,P
COMMON XT(15,35),YT(15,35),X(15,30),Y(15,30),HLIQ,HVAP
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),EQ(15),A(16,6)
COMMON AH(15),BH(15),CH(15),DH(15),BBMIX(35),AAOB(35),ZC(35)
COMMON JA1,JA2,JA3,JA4,JA5,JA6,JA7,DDELMX(35)
DIMENSION DL(30),DV(30)
DIMENSION AX(30),BX(30),DX(30),EP(30),DP(30)
DIMENSION LT(30),VT(30),FEH(30),Q(30),HL(30),HV(30),E(30),DT(30)
DIMENSION DGH(30,31),HLN(2),HVN(2)
DIMENSION LOX(15,1),BCU(15)
DIMENSION F(15),LO(15),T(30),TI(30),L(30),V(30),AF(30),S(30)
DIMENSION TOP(15),BOT(15),BD(15),VD(15,30),LB(15,30),DCU(15)
DIMENSION CPNT(15,2),ZF(15)

```

INPUT/OUTPUT FORMATS

```

100 FORMAT(1X,25I3)
101 FORMAT(8F10.0)
102 FORMAT(6F10.4)
103 FORMAT(4F10.4)
104 FORMAT(1HJ,2HL(,I2,8H) ENTH =,E15.8,15H STREAM HEAT =,E15.8)
105 FORMAT(1HJ,2HV(,I2,8H) ENTH =,E15.8,15H STREAM HEAT =,E15.8)
106 FORMAT(1HJ,2HV(,I2,8H) ENTH =,E15.8,15H STREAM HEAT =,E15.8)
107 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
108 FORMAT(1X,4E14.7)
110 FORMAT(1H1/1HK,40X,12HPROBLEM NO. ,I2)
111 FORMAT(40X,17HPROBLEM STATEMENT)
112 FORMAT(1HK,43X,8HABSORBER)
113 FORMAT(1HL,17X,15HA. COLUMN DATA)
114 FORMAT(1HJ,27X,15HPRESSURE (PSIA),10X,
116HNUMBER OF PLATES)
116 FORMAT(1HK,19X,21HINTER HEATER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
117 FORMAT(1HJ,31X,F7.1,22X,I2)
118 FORMAT(1HK,19X,21HINTER COOLER ON PLATE,I3,
114H WITH DUTY OF,F10.0,9H BTU/U.T.)
119 FORMAT(1HL,17X,13HB. FEED DATA)
120 FORMAT(1HJ,37X,19HTEMPERATURE (DEG F),8X,9HCONDITION)
121 FORMAT(20X,4HFEED,20X,F6.1,12X,16HSATURATED VAPOUR)
125 FORMAT(20X,12HABSORBER OIL,12X,F6.1,11X,
117HSUB-COOLED LIQUID)
126 FORMAT(1HK,41X,4HFEED,16X,12HABSORBER OIL)
127 FORMAT(21X,10HCOMPONENTS,4X,8HLB MOLES,5X,4HMOLE,7X,

```



```

18HLB MOLES,5X,4HMOLE)
128 FORMAT(35X,8HPER U.T.,3X,8HFRACTION,5X,8HPER U.T.,3X,
18HFRACTION)
129 FORMAT(20X,2A6,2X,F9.3,3X,F7.4,5X,F9.3,3X,F7.4)
130 FORMAT(1HK,19X,28HSPECIFIED TOP PRODUCT RATE =,F10.3,
114H LB MOLES/U.T.)
132 FORMAT(1HL,17X,17HC. ENTHALPY DATA)
133 FORMAT(1HJ,19X,28HCHAO-SEADER CORRELATION USED)
138 FORMAT(1HL,17X,26HD. EQUILIBRIUM RATIO DATA)
139 FORMAT(1H1)
143 FORMAT(1HL,17X,23HE. INITIAL ASSUMPTIONS)
144 FORMAT(1HJ,39X,15HPLATE VARIABLES)
145 FORMAT(20X,9HPLATE NO.,5X,11HTEMPERATURE,5X,
111HVAPOUR RATE,5X,11HLIQUID RATE)
146 FORMAT(36X,7H(DEG F),8X,10H(LB MOLES),7X,10H(LB MOLES))
147 FORMAT(51X,10H(PER U.T.),7X,10H(PER U.T.))
148 FORMAT(23X,12,10X,F7.2,9X,F8.2,8X,F8.2)
149 FORMAT(1HK,39X,15HPRODUCT STREAMS)
150 FORMAT(1HJ,39X,7H DRY GAS,16X,8H RICH OIL)
151 FORMAT(21X,10HCOMPONENTS,7X,10H(LB MOLES),14X,
110H(LB MOLES))
152 FORMAT(38X,10H(PER U.T.),14X,10H(PER U.T.))
153 FORMAT(20X,2A6,6X,F10.3,14X,F10.3)
154 FORMAT(1HJ,19X,11HTOTAL RATES,7X,F10.3,14X,F10.3)
155 FORMAT(1HJ,19X,16HITERATION NUMBER,I4)
157 FORMAT(1HJ,19X,7H THETA =,F9.6)
163 FORMAT(1HJ,19X,29H THETA CONVERGENCE TOLERANCE =,F9.4)
164 FORMAT(1HJ,19X,38HPRODUCT STREAM CONVERGENCE TOLERANCE =,
1F9.4)
165 FORMAT(1HJ,19X,30HTEMPERATURE WEIGHTING FACTOR =,F6.3)
168 FORMAT(1HJ,19X,22HNUMBER OF ITERATIONS =,I4)

```

```

C
C READ IN PROBLEM DATA
C

```

```

IFEED=0
ITER=0
WT=1.0
READ(5,100) NC,NHC,NN,NQ1,NQ2,NOPROB
NT=NN+1
NCP=NC+NHC
READ(5,101)(F(I),I=1,NCP)
READ(5,101)(LO(I),I=1,NCP)
READ(5,101)(T(N),N=1,NN)
READ(5,101)(L(N),N=1,NN)
READ(5,101)(V(N),N=1,NN)
READ(5,101) P,TLO,DS,Q1,Q2,TF
VV=.001*DS
READ(5,100) JA1,JA2,JA3,JA4,JA5,JA6,JA7
READ(5,101)((A(I,J),I=1,16),J=1,6)
DO 26 I=1,NC
READ(5,107) TC(I),PC(I),W(I),DELTA(I),V1(I),(CPNT(I,J),J=1,2)
26 READ(5,108) AH(I),BH(I),CH(I),DH(I)

```



```

      IF(NCP.LE.NC) GO TO 27
      CALL PHYS(CPNT)
27 MNN=NN-1
C
C   CALCULATE FEED MOLE FRACTIONS AND ENTHALPIES
C
      FT=0.
      LOT=0.
      DO 23 I=1,NCP
        FT=FT+F(I)
23  LOT=LOT+LO(I)
      DO 230 I=1,NCP
        LOX(I,1)=LO(I)/LOT
        ZF(I)=F(I)/FT
        J=NT+2
        XT(I,J)=ZF(I)
        J=NT+1
230  XT(I,J)=LOX(I,1)
      17 KENTH=2
        J=NT+2
        CALL ENTHAL(TF,XT,KENTH,J)
        ENTH=HVAP
        HF=ENTH*FT
        KENTH=4
        J=NT+1
        CALL ENTHAL(TLO,XT,KENTH,J)
        ENTH=HLIQ
        HAB=ENTH*LOT
C
C   PRINT OUT PROBLEM STATEMENT
C
      WRITE(6,110) NOPROB
      WRITE(6,111)
      WRITE(6,112)
      WRITE(6,113)
      WRITE(6,114)
      WRITE(6,117) P,NN
      IF(NQ1.GT.NN) GO TO 66
      IF(Q1.LT.0.) GO TO 63
      WRITE(6,118) NQ1,Q1
      GO TO 66
63  WRITE(6,116) NQ1,Q1
66  IF(NQ2.GT.NN) GO TO 62
      IF(Q2.LT.0.) GO TO 65
      WRITE(6,118) NQ2,Q2
      GO TO 62
65  WRITE(6,116) NQ2,Q2
62  WRITE(6,164) VV
      WRITE(6,165) WT
      WRITE(6,119)
      WRITE(6,120)
      WRITE(6,121) TF

```



```

WRITE(6,125) TLO
WRITE(6,126)
WRITE(6,127)
WRITE(6,128)
DO 69 I=1,NCP
WRITE(6,129)(CPNT(I,J),J=1,2),F(I),ZF(I),LO(I),LOX(I,1)
69 CONTINUE
WRITE(6,130) DS
WRITE(6,139)
WRITE(6,132)
WRITE(6,133)
68 WRITE(6,138)
WRITE(6,133)
74 WRITE(6,143)
WRITE(6,144)
WRITE(6,145)
WRITE(6,146)
WRITE(6,147)
DO 72 N=1,NN
WRITE(6,148)N,T(N),V(N),L(N)
72 CONTINUE
WRITE(6,139)

C
C BEGIN SOLUTION OF PROBLEM
C
1000 CONTINUE
ITER=ITER+1
WRITE(6,155) ITER

C
C CALCULATE K RATIOS, ABSORPTION FACTORS AND STRIPPING
C FACTORS
C
1001 DO 2 I=1,NCP
IF( ITER.LT.2) GO TO 28
DO 25 N=1,NN
KENTH=5
CALL K(T(N),KENTH,N)
AF(N)=L(N)/(EQ(I)*V(N))
25 S(N)=1./AF(N)
GO TO 29
28 DO 30 N=1,NN
CALL KIDL(T(N))
AF(N)=L(N)/(EQ(I)*V(N))
30 S(N)=1./AF(N)
29 LOI=LO(I)
FI=F(I)

C
C CALCULATE B/D RATIOS
C
AA=AF(1)
BB=1.
DO 1 N=3,NT

```



```

    AFI=AF(N-1)
    AA=AA*AFI
1   BB=BB*AFI+1.
    BD(I)=(AA*LOI+FI*(AA+BB-1.))/(FI+BB*LOI)
    D=(LOI+FI)/(1.+BD(I))
    TOP(I)=D
    B=BD(I)*D
    BOT(I)=B

```

```

C
C   CALCULATE L/B AND V/D VALUES
C

```

```

    LOD1=FI/D-BD(I)
    VD(I,1)=1.
    DO 3 N=2,NN
3   VD(I,N)=AF(N-1)*VD(I,N-1)+LOD1
    F1B=LOI/B-1./BD(I)
    LB(I,NN)=1.
    DO 4 N=1,MNN
    J=1+NN-N
4   LB(I,J-1)=S(J)*LB(I,J)+F1B

```

```

C
C   CALCULATE ROUND-OFF ERRORS
C

```

```

    BDTP=1./(LB(I,1)*S(1))
    BDB=VD(I,NN)*AF(NN)
    RTP=BDTP/BD(I)
    RB=BDB/BD(I)
    IF(ABS(RTP-1.).LE.ABS(RB-1.)) GO TO 5
    DO 7 N=1,NN
7   LB(I,N)=VD(I,N)*AF(N)/BD(I)
    GO TO 200
5   DO 6 N=1,NN
6   VD(I,N)=LB(I,N)*S(N)*BD(I)
200 CONTINUE
2   CONTINUE
    BOTS=0.
    TOPS=0.
    DO 24 I=1,NCP
    BOTS=BOTS+BOT(I)
24  TOPS=TOPS+TOP(I)

```

```

C
C   CALCULATE NEW FLOW PROFILES
C

```

```

98  DO 11 N=1,NN
    SV=0.
    SL=0.
    DO 12 I=1,NCP
    SV=SV+VD(I,N)*TOP(I)
12  SL=SL+LB(I,N)*BOT(I)
    LT(N)=SL
    VT(N)=SV
    DV(N)=V(N)-VT(N)

```



```

DL(N)=L(N)-LT(N)
V(N)=VT(N)
L(N)=LT(N)

```

C
C
C

CALCULATE NEW MOLE FRACTIONS

```

DO 11 I=1,NCP
X(I,N)=LB(I,N)*BOT(I)/SL
Y(I,N)=VD(I,N)*TOP(I)/SV
XT(I,N)=X(I,N)
YT(I,N)=Y(I,N)
11 CONTINUE

```

C
C
C

CALCULATE NEW TEMPERATURE PROFILE

```

DO 31 N=1,NN
Q(N)=0.
TI(N)=T(N)
31 FEH(N)=0.
FEH(1)=HAB
FEH(NN)=HF
Q(NQ1)=Q1
Q(NQ2)=Q2
MN=NN+1
DO 32 N=1,NN
DELT=0.5
KQ=1
I(N)=TI(N)-DELT
33 KENTH=2
CALL ENTHAL(T(N),YT,KENTH,N)
ENTH=HVAP
HVN(KQ)=ENTH
KENTH=3
CALL ENTHAL(T(N),XT,KENTH,N)
ENTH=HLIQ
HLN(KQ)=ENTH
34 IF(KQ.GT.1) GO TO 35
T(N)=TI(N)+DELT
KQ=2
GO TO 33
35 DELT=DELT*2.
DX(N)=V(N)*(HVN(2)-HVN(1))/DELT
BX(N)=L(N)*(HLN(2)-HLN(1))/DELT
AX(N)=BX(N)+DX(N)
HL(N)=HLN(1)
32 HV(N)=HVN(1)
DO 36 N=1,NN
M=N
IF(N.LT.2) GO TO 37
AA=(-L(N-1))*HL(N-1)
38 BB=0.
IF(N.LT.NN) GO TO 39

```



```

40 E(N)=-Q(N)-FEH(N)+AA+L(N)*HL(N)+V(N)*HV(N)+BB
   E(N)=-E(N)
   GO TO 36
37 AA=0.
   GO TO 38
39 BB=(-V(N+1))*HV(N+1)
   GO TO 40
36 CONTINUE
   EP(1)=E(1)/AX(1)
   DP(2)=DX(2)/AX(1)
   NX=NN-1
   DO 41 N=2,NN
   EP(N)=(E(N)+BX(N-1)*EP(N-1))/(AX(N)-BX(N-1)*DP(N))
   IF(N.GT.NX) GO TO 41
   DP(N+1)=DX(N+1)/(AX(N)-BX(N-1)*DP(N))
41 CONTINUE
   DT(NN)=EP(NN)
   DO 43 N=1,NX
   J=NX+1-N
43 DT(J)=EP(J)+DP(J+1)*DT(J+1)
   KTEMP=0
   DO 42 N=1,NN
   T(N)=TI(N)+WT*DT(N)
   IF(ABS(DT(N)).GT..01) KTEMP=KTEMP+1
42 CONTINUE
   IF(KTEMP.LT.1) GO TO 99
   GO TO 1000
99 CONTINUE

```

```

C
C   PRINT OUT RESULTS
C
   WRITE(6,110) NOPROB
   WRITE(6,149)
   WRITE(6,150)
   WRITE(6,151)
   WRITE(6,152)
   DO 16 I=1,NCP
   WRITE(6,153)(CPNT(I,J),J=1,2),TOP(I),BOT(I)
16 CONTINUE
   WRITE(6,154) TOPS,BOTS
   WRITE(6,144)
   WRITE(6,145)
   WRITE(6,146)
   WRITE(6,147)
   DO 77 N=1,NN
   WRITE(6,148) N,T(N),V(N),L(N)
77 CONTINUE
   WRITE(6,168) ITER
C
C   ADJUST FEED TEMPERATURE TO FIT DESIRED OVERHEAD PRODUCT
C   AND GO THROUGH A NEW ITERATION
C

```



```
IF(IFEED.GT.0) GO TO 91
QQ1=V(1)-DS
IF(ABS(QQ1).LT.VV) GO TO 97
TF1=TF
IF(QQ1.GT.0.) GO TO 90
TF=TF+20.
IFEED=1
GO TO 17
90 TF=TF-20.
IFEED=1
GO TO 17
91 QQ2=V(1)-DS
IF(ABS(QQ2).LT.VV) GO TO 97
TF2=TF
SLOPE=(QQ2-QQ1)/(TF2-TF1)
TF=TF2-QQ2/SLOPE
TF1=TF2
QQ1=QQ2
GO TO 17
97 CALL EXIT
END
```


APPENDIX B ANNEX 4

THIS PROGRAM ATTEMPTS TO SOLVE A REBOILED ABSORBER PROBLEM BY THE
SUM RATES METHOD

```
COMMON XT(15,35),YT(15,35)
COMMON NC,NHC,NCP,P,FR(3),FL(3),FV(3),XF(15,3),YF(15,3),ZF(15,3)
COMMON XM(15,3),YM(15,3),ABLX(15,1),X(15,35),Y(15,35),HLIQ,HVAP
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),EQ(15),A(16,6)
COMMON AH(15),BH(15),CH(15),DH(15),BBMIX(35),AAOB(35),ZC(35)
COMMON JA1,JA2,JA3,JA4,JA5,JA6,JA7,DDELMX(35)
DIMENSION DV(30),DL(30)
DIMENSION CPNT(15,2),E(30)
DIMENSION AX(30),BX(30),DX(30),DP(30),EP(30),HV(30),HL(30)
DIMENSION Q(30),FEH(30),DT(30),LT(30),VT(30),HVN(3),HLN(3)
DIMENSION TH(5),DTH(5),THN(5),GP(5,5),GT(5),G(5)
DIMENSION WCU(15),WD(15),ww(15),DCO(15),BCO(15),TOP(15),BUT(15)
DIMENSION ZM(15,3),LO(15),AF(30),S(30)
DIMENSION LB(15,30),VD(15,30),ZB(3),ZD(3),VFB(30),LFD(30),BD(15)
DIMENSION L(30),V(30),T(30),TI(30),VF(30),LF(30)
DIMENSION ABLM(15,1)
INTEGER ABLF,FC
REAL K,KCONST,LF,L,LB,LO,LOD,LFD,JJ,II,LN,LNN,LOD1
REAL LT,LH,LHN
REAL LOI
```

INPUT/OUTPUT FORMATS

```
100 FORMAT(25I3)
101 FORMAT(5E16.8)
102 FORMAT(1X,4E14.7)
103 FORMAT(1X,2F7.1,F7.4,F6.3,F7.2,33X,2A6)
104 FORMAT(1HJ,10HCONVERGENT)
105 FORMAT(1X,3(I2,F8.0))
106 FORMAT(1X,11E11.4)
107 FORMAT(8F10.4)
109 FORMAT(10F8.0)
110 FORMAT(6F10.4)
111 FORMAT(4F10.4)
112 FORMAT(1X,I2,3E16.8)
113 FORMAT(1X,2H N,6X,2H T,15X,2H L,15X,2H V)
114 FORMAT(1HJ,4HW(I),3X,5E16.8)
117 FORMAT(1HJ,2HL(,I2,12H) ENTHALPY =,E15.8,22H STREAM HEAT CONTENT =
1,E15.8)
118 FORMAT(1HJ,2HV(,I2,12H) ENTHALPY =,E15.8,22H STREAM HEAT CONTENT =
1,E15.8)
120 FORMAT(1X,4E16.8)
121 FORMAT(8X,2HAH,15X,2HBH,15X,2HCH,15X,2HDH)
122 FORMAT(1X,8E16.8)
```



```

123 FORMAT(1X,27HMOLES OF COMPONENT IN FEED,I3)
124 FORMAT(1X,36HMOLE FRACTIONS OF COMPONENTS IN FEED,I3)
125 FORMAT(1X,24HMOLE FRACTION IN ABS LIQ)
126 FORMAT(1HJ,25HMOLES OF ABSORBER LIQUID ,E15.8)
130 FORMAT(1X,25H L/B RATIOS FOR COMPONENT,I3)
131 FORMAT(6(1X,I2,E16.8))
132 FORMAT(1X,25H V/D RATIOS FOR COMPONENT,I3)
135 FORMAT(1X,3HFT=,E15.8)
136 FORMAT(1HJ,24HCALCULATED TOP PRODUCT =,E15.8)
137 FORMAT(1X,3HTH(,I2,2H)=,E15.8)
138 FORMAT(1X,3Hw1=,E15.8)
142 FORMAT(1HJ,2H N,3H I,8X,1HX,15X,1HY,14X,2HSL,14X,2HSV)
143 FORMAT(1X,2I3,4E16.8)
145 FORMAT(1X,2HV(,I2,2H)=,E15.8,3H L(,I2,2H)=,E15.8,4H QC=,E15.8)
146 FORMAT(1X,15HREBOILER LOAD =,E15.8)
160 FORMAT(1X,4H RTP=,E15.8,6H RF1=,E15.8)
161 FORMAT(1X,2HT(,I2,2H)=,E15.8,5X,E15.8)
900 FORMAT(1HJ,10HINPUT DATA)
902 FORMAT(1HK,22HNUMBER OF COMPONENTS =,I3)
903 FORMAT(1HJ,45HTOTAL NUMBER OF PLATES (INCLUDING REBOILER) =,I3)
904 FORMAT(1HJ,28HSPECIFIED TOP PRODUCT RATE =,E15.8,6H MOLES)
905 FORMAT(1HJ,17HCOLUMN PRESSURE =,F6.1,5H PSIA)
906 FORMAT(1HJ,27H SIDE STREAM FROM PLATE NN =,E15.8)
910 FORMAT(1HL,17HITERATION NUMBER ,I3)

```

C
C
C

READ IN PROBLEM DATA

```

WT=0.25
THV=.001
BPTV=.0001
VVL=0.2
ITER=0
KITER=10
READ(5,100) NC,NHC,NN,NF1,NQ1,NQ2
READ(5,101) QR,Q1,Q2
NCP=NC+NHC
NNF1=NF1+1
MNF1=NF1-1
NT=NN+1
READ(5,101) FR(1),ABLR,TOPPR,SS1,P
VV=.001*TOPPR
READ(5,105) FC,FT,ABLF,ABLT
READ(5,109)(T(N),N=1,NT)
READ(5,109)(V(N),N=1,NT)
READ(5,109)(L(N),N=1,NT)
READ(5,100) JA1,JA2,JA3, JA4,JA5,JA6,JA7
READ(5,107)((A(I,J),I=1,16),J=1,6)
DO 1 I=1,NC
READ(5,103) TC(I),PC(I),W(I),DELTA(I),V1(I),(CPNT(I,J),J=1,2)
READ(5,101) ZM(I,1),ABLM(I,1)
1 READ(5,102) AH(I),BH(I),CH(I),DH(I)
IF(NCP.LE.NC) GO TO 2

```



```

CALL PHYS(CPNT,ZM,ABLM)
2 CONTINUE
WRITE(6,900)
WRITE(6,902) NCP
WRITE(6,903) NT
WRITE(6,905) P
WRITE(6,904) TOPPR
WRITE(6,906) SS1
WRITE(6,121)
WRITE(6,120)(AH(I),BH(I),CH(I),DH(I),I=1,NCP)

```

```

C
C CALCULATE FEED RATES
C

```

```

ABT=0.
ZT=0.
DO 4 I=1,NCP
ABT=ABT+ABLM(I,1)
4 ZT=ZT+ZM(I,1)
V(1)=TOPPR
L(NT)=ZT+ABT-SS1-TOPPR
N=NT+2
DO 3 I=1,NCP
ZF(I,1)=ZM(I,1)/FR(1)
ABLX(I,1)=ABLM(I,1)/ABT
LO(I)=ABLM(I,1)
XT(I,N)=ABLX(I,1)
3 CONTINUE
J=1
WRITE(6,123) J
WRITE(6,122)(ZM(I,J),I=1,NCP)
WRITE(6,124) J
WRITE(6,122)(ZF(I,J),I=1,NCP)
WRITE(6,126) ABLR
WRITE(6,125)
J=1
WRITE(6,122)(ABLX(I,J),I=1,NCP)
WRITE(6,113)
DO 11 N=1,NT
WRITE(6,112)N,T(N),L(N),V(N)
11 CONTINUE

```

```

C
C SET FEED CONDITIONS
C

```

```

W1=SS1
KENTH=4
N=NT+2
CALL ENTHAL(ABLT,XT,KENTH,N)
ENTH=HLIQ
HAB=ENTH*ABLR
WRITE(6,117) N,ENTH,HAB
N=NT+1
IF(FC.EQ.1) GO TO 7

```



```

IF(FC.EQ.2) GO TO 8
J=1
CALL FLASH(FT,J,N)
WRITE(6,170) FL(1),FV(1)
170 FORMAT(1HJ,3HFL=,E16.8,5H FV=,E16.8)
WRITE(6,142)
DO 5 I=1,NCP
WRITE(6,143) N,I,XF(I,1),YF(I,1)
XT(I,N)=XF(I,1)
5 YT(I,N)=YF(I,1)
KENTH=3
CALL ENTHAL(FT,XT,KENTH,N)
ENTH=HLIQ
HX=ENTH
KENTH=2
CALL ENTHAL(FT,YT,KENTH,N)
ENTH=HVAP
HY=ENTH
GO TO 6
7 FL(J)=FR(J)
FV(J)=0.
J=1
DO 90 I=1,NCP
XM(I,J)=ZM(I,J)
YM(I,J)=0.
XF(I,J)=ZF(I,J)
YF(I,1)=0.
XT(I,N)=XF(I,1)
90 YT(I,N)=YF(I,1)
KENTH=3
CALL ENTHAL(FT,XT,KENTH,N)
ENTH=HLIQ
HX=ENTH
HY=0.
GO TO 6
8 FL(J)=0.
FV(J)=FR(J)
J=1
DO 91 I=1,NCP
XM(I,J)=0.
YM(I,J)=ZM(I,J)
XF(I,J)=0.
YF(I,1)=ZF(I,1)
XT(I,N)=XF(I,1)
91 YT(I,N)=YF(I,1)
CALL DEWPT(FT,YT,N)
KENTH=2
CALL ENTHAL(FT,YT,KENTH,N)
ENTH=HVAP
WRITE(6,118) N,ENTH
HY=ENTH
HX=0.

```



```

6 HF=(FV(J)*HY+FL(J)*HX)/FR(J)
  SHF=HF*FR(J)
  WRITE(6,135) FT
  WRITE(6,118) N,ENTH,SHF
  DO 9 N=1,NT
  VF(N)=0.
9 LF(N)=0.
  N=NF1
  VF(N)=FV(J)
  LF(N)=FL(J)

```

```

C
C BEGIN ITERATION
C

```

```

1000 ITER=ITER+1
  WRITE(6,910) ITER
  CALL FPTSW
  DO 44 I=1,NCP
  IF(ITER.LT.2) GO TO 14
  KENTH=5
  CALL K(T(N),KENTH,N)
  DO 92 N=1,NT
  AF(N)=L(N)/(EQ(I)*V(N))
92 S(N)=1./AF(N)
  GO TO 15
14 DO 13 N=1,NT
  CALL KIDL(T(N))
  AF(N)=L(N)/(EQ(I)*V(N))
13 S(N)=1./AF(N)
15 LOI=LO(I)

```

```

C
C CALCULATE RATIOS
C

```

```

C
C UP
C

```

```

  JJ=1.
  II=1.
  BB=0.
  AA=1.
  DO 17 N=1,NT
  J=1+NT-N
  SF=S(J)
  IF(J.GT.MNF1) GO TO 18
  JJ=JJ*SF+1.
  II=II*SF
18 BB=BB*SF+1.
  AA=AA*SF
17 CONTINUE
  ZT=LOI+JJ*ZM(I,1)-II*YM(I,1)
  C1=1.+SS1*(S(NT)+1.)/(L(NN)-SS1)
  BDUP=ZT/((AA+BB*C1)*(LOI+ZM(I,1))-(C1*ZT))
  BUP=(LOI+ZM(I,1))/(C1+1.0/BDUP)

```



```

      DUP=BUP/BDUP
      WRITE(6,133) BDUP,DUP,BUP
133  FORMAT(1X,7H BDUP=,E15.8,7H DUP=,E15.8,7H BUP=,E15.8)
      AA=AF(1)
      BB=1.
      DO 21 N=3,NF1
      AFI=AF(N-1)
      AA=AA*AFI
21  BB=BB*AFI+1.

```

C
C
C CALCULATE VFB AND ZB

```

      DO 34 N=1,NT
      LFD(N)=0.
34  VFB(N)=0.
      VFB(MNF1)=YM(I,1)/BUP
      ZB(1)=0.
      LB(I,NT)=1.
      NX=NN-1
      LB(I,NN)=L(NN)*(S(NT)+1.)/(L(NN)-SS1)
      DO 26 N=1,NX
      J=1+NX-N
      IF(J.EQ.MNF1) ZB(1)=ZM(I,1)/BUP
      LB(I,J)=LB(I,J+1)*S(J+1)+C1+VFB(J)-ZB(1)
26  CONTINUE
      VBNF1=LB(I,NF1)*S(NF1)
      AK=AA+BB
      CJ=XM(I,1)-ZM(I,1)-BB*LOI
      ZT=ZM(I,1)+LOI
      WB=C1-1.0
      WDT=1.+WB*BDUP
      BDDOWN=(AK*ZT+CJ*WDT)/(VBNF1*ZT-CJ)
      DDOWN=ZT/(BDDOWN+WDT)
      BDOWN=BDDOWN*DDOWN
      WRITE(6,134) BDDOWN,DDOWN,BDOWN
134  FORMAT(1X,7HBDDOWN=,E15.8,7H DDOWN=,E15.8,7H BDOWN=,E15.8)

```

C
C
C CALCULATE LFD AND XD

```

      LOD1=1.-LOI/DDOWN
      ZD(1)=0.
      LFD(NF1)=XM(I,1)/DDOWN
      VD(I,1)=1.
      DO 45 N=2,NT
      IF(N.EQ.NF1) GO TO 47
      GO TO 998
47  ZD(1)=ZM(I,1)/DDOWN
998  SPARE=LOD1-ZD(1)+LFD(N)
45  VD(I,N)=AF(N-1)*VD(I,N-1)+SPARE

```

C
C
C CALCULATE ROUND OFF ERROR


```

    BDTP=1./(S(1)*LB(I,1))
    BDF1=AF(NF1)*VD(I,NF1)/LB(I,NF1)
    RTP=BDTP/BDUP
    RF1=BDF1/BDDOWN
    WRITE(6,160) RTP,RF1
    IF(ABS(RTP-1.).LE.ABS(RF1-1.)) GO TO 53
    BD(I)=BDDOWN
    TOP(I)=DDOWN
    BOT(I)=BDOWN
    DO 55 N=1,NF1
55  LB(I,N)=VD(I,N)*AF(N)/BD(I)
    DO 57 N=NNF1,NT
57  VD(I,N)=LB(I,N)*S(N)*BD(I)
    GO TO 56
53  BD(I)=BDUP
    TOP(I)=DUP
    BOT(I)=BUP
    DO 54 N=1,NT
54  VD(I,N)=LB(I,N)*S(N)*BD(I)
56  WD(I)=AF(NN)*VD(I,NN)*SS1/L(NN)
44  CONTINUE
    CALL FPTSW
    W1=0.
    TOPS=0.
    DO 440 I=1,NCP
    WW(I)=WD(I)*TOP(I)
    W1=W1+WW(I)
440  TOPS=TOPS+TOP(I)
    WRITE(6,114)(WW(I),I=1,NCP)
    WRITE(6,138) W1
    WRITE(6,136) TOPS

```

C

```

    DO 66 N=1,NT
    LT(N)=0.
    VT(N)=0.
    DO 67 I=1,NCP
    VT(N)=VT(N)+VD(I,N)*TOP(I)
67  LT(N)=LT(N)+LB(I,N)*BOT(I)
    DL(N)=LT(N)-L(N)
    DV(N)=VT(N)-V(N)
    L(N)=LT(N)
    V(N)=VT(N)
    DO 66 I=1,NCP
    X(I,N)=LB(I,N)*BOT(I)/LT(N)
    Y(I,N)=VD(I,N)*TOP(I)/VT(N)
66  CONTINUE

```

C

C

TEMPERATURE PROFILE BY SUM RATES METHOD

C

```

    DO 675 N=1,NT
    Q(N)=0.
    TI(N)=T(N)

```



```

675 FEH(N)=0.
    Q(NQ1)=Q1
    Q(NQ2)=Q2
    Q(NT)=QR
    FEH(1)=HAB
    FEH(NF1)=HF*FR(1)

```

C
C
C

TEMPERATURE PROFILE BY SUM-RATES METHOD

```

    MT=NT+1
    DO 662 N=1,NT
    DELT=0.5
    KQ=1
    T(N)=TI(N)-DELT
663 KENTH=2
    CALL ENTHAL(T(N),Y,KENTH,N)
    ENTH=HVAP
    HVN(KQ)=ENTH
    KENTH=3
    CALL ENTHAL(T(N),X,KENTH,N)
    ENTH=HLIQ
    HLN(KQ)=ENTH
666 IF(KQ.GT.1) GO TO 661
    T(N)=TI(N)+DELT
    KQ=2
    GO TO 663
661 IF(KQ.GT.2) GO TO 659
    T(N)=TI(N)
    KQ=3
    GO TO 663
659 DELT=DELT*2.
    BX(N)=LT(N)*(HLN(2)-HLN(1))/DELT
    DX(N)=VT(N)*(HVN(2)-HVN(1))/DELT
    AX(N)=DX(N)+BX(N)
    IF(N.EQ.NN) BX(N)=BX(N)-SS1*BX(N)/LT(NN)
    HL(N)=HLN(3)
    HV(N)=HVN(3)
662 CONTINUE
    DO 665 N=1,NT
    IF(N.LT.2) GO TO 672
    AA=-LT(N-1)*HL(N-1)
664 IF(N.GT.NN) GO TO 669
    BB=-VT(N+1)*HV(N+1)
673 E(N)=-Q(N)-FEH(N)+AA+LT(N)*HL(N)+VT(N)*HV(N)+BB
    E(N)=-E(N)
    GO TO 665
672 AA=0.
    GO TO 664
669 BB=0.
    AA=-(LT(N-1)-SS1)*HL(N-1)
    GO TO 673
665 CONTINUE

```



```

EP(1)=E(1)/AX(1)
DP(2)=DX(2)/AX(1)
DO 667 N=2,NT
EP(N)=(E(N)+BX(N-1)*EP(N-1))/(AX(N)-BX(N-1)*DP(N))
IF(N.GT.NN) GO TO 667
DP(N+1)=DX(N+1)/(AX(N)-BX(N-1)*DP(N))
667 CONTINUE
DT(NT)=EP(NT)
DO 679 N=1,NN
J=NN+1-N
679 DT(J)=EP(J)+DP(J+1)*DT(J+1)
WRITE(6,106)(DT(N),N=1,NT)
WRITE(6,150)
150 FORMAT(1X,2H N,7X,2H T,14X,2HDT,14X,2H V,14X,2H DV,14X,2H L,14X,
12HDL)
KTEMP=0
681 DO 680 N=1,NT
IF(ABS(DT(N)).GT.0.01) KTEMP=KTEMP+1
T(N)=TI(N)+WT*DT(N)
IF(T(N).GT.550.) T(N)=550.
IF(T(N).LT.0.) T(N)=0.
WRITE(6,151) N,T(N),DT(N),V(N),DV(N),L(N),DL(N)
151 FORMAT(1X,I2,6E16.8)
680 CONTINUE
IF(KTEMP.LT.1) GO TO 941
GO TO 1000
941 WRITE(6,104)
CALL EXIT
END

```


Annex 5

AA	dummy variable
A(I,J)	equilibrium ratio constants
AAOB(N)	A_m/B_m of Redlich Kwong equation of state
AF(N)	Absorption factor on stage N for a component
AH(I)	enthalpy constant
AK	dummy variable
AX(N)	a_n from sum rates matrix solution
BB	dummy variable
BBMIX(N)	B_m of Redlich Kwong equation
BCO(I)	corrected b_i after θ factor calculation
BD(I)	round off error free (b/d) ratio
BDBOT	$(b/d)_{\text{bottom}}$ ratio
BDDOWN	$(b/d)_{\text{down}}$ ratio
BDNF1	$(b/d)_{\text{NF1}}$ ratio
BDTOP	$(b/d)_{\text{top}}$ ratio
BDUP	$(b/d)_{\text{up}}$ ratio
BDOWN	moles of component i in bottom product as calculated from $(b/d)_{\text{down}}$
BH(I)	enthalpy constant
BOT(I)	moles of component i in bottom product
BOTS	calculated bottom product
BPTV	convergence tolerance on bubble point calculations
BUP	moles of component in bottom product as calculated from $(b/d)_{\text{up}}$
BX(N)	b_n from sum rates matrix solution
CH(I)	enthalpy constant
CPNT(I,J)	component name

DCO(I)	corrected d_i after θ convergence technique
DDELMX(N)	δ_m from Chao-Seader correlation
DDOWN	moles of component in top product as calculated from $(b/d)_{\text{down}}$
DELTA(I)	δ_i (solubility parameter)
DH(I)	enthalpy constant
DP(N)	d'_n from sum rates matrix solution
DPTV	convergence tolerance in dew point calculation
DS	specified top product rate
DUP	moles of component in top product as calculated from $(b/d)_{\text{up}}$
DX(N)	d_n from sum rates matrix solution
E(N)	E_n from sum rates matrix solution
EH(I)	enthalpy constant for polynomial data
EP(N)	E'_n from sum rates matrix solution
EQ(I)	equilibrium ratio of component i
ER(I,N)	equilibrium ratio of component i on plate n
F(I)	moles of component i in feed stream
FC	feed condition 1 = superheated vapor 2 = saturated vapor 3 = saturated liquid 4 = subcooled liquid 5 = vapor/liquid mixture
FH(I)	enthalpy constants for polynomial data
FL	moles of liquid in feed
FR	feed rate in moles
FV	moles of vapor in feed
G(J)	
GP(J,K)	variables in the θ convergence technique
GT(J)	

HB	enthalpy of bottom product
HV1	enthalpy of stream V(1)
HW1	enthalpy of side stream product
JH2	component number of hydrogen
JC1	component number of methane
JN2	component number of nitrogen
JO2	component number of oxygen
JCO	component number of carbon monoxide
JCO2	component number of carbon dioxide
JH2S	component number of hydrogen sulfide
KDATA	switch for data set used 0 - Chao-Seader data 1 - NGAA and Yen and Alexander data 2 - Polynomial data used
KENTH	switch for enthalpy and equilibrium value subroutines 1 - superheated vapor enthalpy - vapor section of Chao-Seader K value subprogram to be used 2 - saturated vapor enthalpy - vapor section of Chao-Seader K value subprogram to be used 3 - saturated liquid enthalpy - liquid section of Chao-Seader K value subprogram to be used 4 - subcooled liquid enthalpy - liquid section of Chao-Seader K value subprogram to be used 5 - component molal enthalpies calculated in Yen and Alexander data - complete K value subroutine used in Chao-Seader
L(N)	liquid flow rate from plate n
LB(I,N)	\ln/b for component i
LO(I)	moles of component i in absorber oil
LOX(I)	mole fraction in lean oil
LOR	absorber oil rate

LT(N)	summation of component molal liquid rates from plate n
NT	total number of plates in reboiled absorber (including reboiler)
NN	total number of plates in absorber
NF1	feed plate number
NQ1	Intercooler plate number
NQ2	Intercooler plate number
NC	number of conventional components
NHC	number of hypothetical components
NCP	total number of components
P	pressure
PCONV	convergence pressure
PC(I)	critical pressure of component i
Q1	intercooler/heater duty of intercooler/heater No. 1
Q2	intercooler/heater duty of intercooler/heater No. 2
Q(N)	intercooler/heater load on plate n (In sum rates programs intercooler heat loads are negative) (In bubble point programs intercooler heat loads are positive)
RTOP RBOT RNFL	round-off error ratios
S(N)	stripping factor for a component on plate n
T(N)	temperature on plate n
TI(N)	temporary storage T(N) between iterations
TC(I)	critical temperature of component i
TF	feed temperature
TH(J)	Theta
THV	convergence tolerance on theta

TLO	temperature of lean oil
TOP(I)	moles of i in top product
TOPS	calculated top product
V1(I)	specific volume of component i
V(N)	vapor flow rate from plate n
VV	convergence tolerance on product stream
VD(I,N)	v_n/d for component i
VMAX1 VMIN1	maximum and minimum vapor flow rates for any plate above the feed plate
VMAX2 VMIN2	maximum and minimum vapor flow rates for any plate below the feed plate
VT(N)	summation of component molal vapor rates from plate n
W(I)	acentric factor (ω) of component i
WCO(I)	corrected WW(I) after theta convergence technique
WD(I)	w/d for component i
WT	temperature weighting factor
WW(I)	moles of component i in side stream
W1	calculated side stream rate
X(I,N)	liquid mole fraction of i on plate n
XT(I,N)	liquid mole fraction of i on plate n (temporary storage)
XF(I)	mole fraction of component i in liquid feed
XM(I)	moles of component i in liquid feed stream
Y(I,N)	vapor mole fraction of component i on plate n
YT(I,N)	vapor mole fraction of component i on plate n (Temporary storage)

YF(I)	mole fraction of component i in vapor feed stream
YM(I)	moles of component i in vapor feed stream
ZC(I)	critical compressibility factor of component i
ZC(N)	critical compressibility factor of mixture on plate n
ZF(I)	mole fraction of i in total feed
ZM(I)	total moles of i in feed

APPENDIX C

SUB-PROGRAMS FOR USE WITH NGAA
AND YEN AND ALEXANDER DATA

SUBROUTINE PHYS(CPNT)

THIS SUBROUTINE CALCULATES THE TEMPERATURE COEFFICIENTS
FOR THE NGAA EQUILIBRIUM DATA CORRELATION

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION CPNT(15,2)
DIMENSION C(4),B(7)
PP=ALOG(P)/10.
DO 1 I=1,NCP
DO 1 JJ=1,4
READ(5,103) PCV,NKP,KK,(J,B(J),J=1,4)
READ(5,103) PCV,NKP,KK,(J,B(J),J=5,7)
103 FORMAT(1X,2I3,12,4(I2,E15.8))
BB=B(1)
DO 2 J=2,7
2 BB=BB+B(J)*(PP**((J-1)))
1 A(I,JJ)=BB
RETURN
END

```


C
C
C
SUBROUTINE KIDL(T)

C
C THIS SUBPROGRAM IS A DUMMY PROGRAM TO CORRESPOND WITH THE
C KIDL SUBPROGRAM OF THE CHAO SEADER SET OF SUBPROGRAMS
C

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LU(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
RETURN
END

SUBROUTINE K(T,KENTH,N)

THIS SUBPROGRAM CALCULATES THE K VALUES FOR THE NGAA DATA

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH

COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)

COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)

COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)

COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA

COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)

COMMON EQ(15)

REAL LKP,LK

TT=T+459.6

TT=TT/1000.

PP=ALOG(P)

DO 2 I=1,NCP

TLKP=A(I,1)

DO 1 J=2,4

1 TLKP=TLKP+A(I,J)*(TT**(J-1))

LKP=TLKP/TT

LK=LKP-PP

2 EQ(I)=EXP(LK)

RETURN

END

SUBROUTINE BUBPT(T,B,N)

THIS SUBPROGRAM CALCULATES THE BUBBLE POINT FOR THE NGAA DATA

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH

COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)

COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)

COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)

COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA

COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)

COMMON EQ(15)

DIMENSION B(15,35)

BPTV=.0001

KT=1

TT=T

1 SY=0.

KENTH=0

CALL K(TT,KENTH,N)

DO 2 I=1,NCP

XT(I,N)=B(I,N)

2 SY=SY+XT(I,N)*EQ(I)

SQ=1.0-SY

IF(ABS(SQ).LT.BPTV) GO TO 4

KT=KT-1

IF(KT.LT.0) GO TO 3

SYO=SY

TO =TT

TT=TT-50.

GO TO 1

3 SLOPE=(SY-SYO)/(TT-TO)

TO=TT

TT=(SQ/SLOPE)+TT

SYO=SY

GO TO 1

4 T=TT

RETURN

END

SUBROUTINE DEWPT(T,B,N)

THIS SUBPROGRAM CALCULATES THE DEWPOINT FOR THE NGAA DATA

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION B(15,35)
TT=T
DPTV=.001
KT=1
1 SX=0.
  KENTH=0
  CALL K(TT,KENTH,N)
  DO 2 I=1,NCP
    YT(I,N)=B(I,N)
    XX=YT(I,N)/EQ(I)
2  SX=SX+XX
  IF(ABS(SX-1.0).LT.DPTV) GO TO 4
  KT=KT-1
  IF(KT.LT.0) GO TO 3
  SX0=SX
  TO=TT
  TT=TT+10.
  GO TO 1
3 SLOPE=(SX-SX0)/(TT-TO)
  TN=((1.0-SX)/SLOPE)+TT
  SX0=SX
  TO=TT
  TT=TN
  GO TO 1
4 T=TT
  RETURN
  END

```


SUBROUTINE FLASH(T,N)

THIS SUBPROGRAM CARRIES OUT FLASH CALCULATIONS FOR THE
NGAA AND YEN AND ALEXANDER DATA SET

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)

Q=1.

GG=0.

VV=.001

3 GS1=0.

GS=0.

KENTH=0

CALL K(T,KENTH,N)

DO 1 I=1,NCP

ZFI=ZF(I)

GKF=1.-1./EQ(I)

G=ZFI/(1.-Q*GKF)

GS=GS+G

G1=ZFI*GKF/((1.-Q*GKF)**2)

1 GS1=GS1+G1

GS=GS-1.

IF(ABS(GS-GG).LT.VV) GO TO 2

GG=GS

Q=Q-GS/GS1

GO TO 3

2 FL=Q*FR

FV=FR-FL

DO 4 I=1,NCP

XF(I)=ZF(I)*FR/(FV*EQ(I)+FL)

YF(I)=EQ(I)*XF(I)

YM(I)=YF(I)*FV

4 XM(I)=XF(I)*FL

RETURN

END


```

C
C
C
SUBROUTINE ENTHAL(TF,B,KENTH,J)

```

```

C
C THIS SUBPROGRAM CALCULATES THE ENTHALPIES USING THE YEN
C AND ALEXANDER DATA SET
C

```

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
COMMON PH(15)
DIMENSION B(15,35)

```

```

100 FORMAT(1X,4H PR=,E15.8,22H OUTSIDE LIMIT KENTH=,I2)
101 FORMAT(1X,4H TR=,E15.8,22H OUTSIDE LIMIT KENTH=,I2)
102 FORMAT(1HJ,40HSUPER HEATED VAPOUR ENTHALPY NOT ENTERED)
103 FORMAT(1HJ,27HZCP LESS THAN 0.22 KENTH= ,I2)

```

```

T=TF+460.

```

```

TX=T/1000.

```

```

TCP=0.

```

```

ZCP=0.

```

```

HP=0.

```

```

PCP=0.

```

```

WMP=0.

```

```

IF(KENTH.EQ.5) GO TO 5

```

```

DO 30 I=1,NCP

```

```

ZCP=ZCP+B(I,J)*ZC(I)

```

```

TCP=TCP+B(I,J)*TC(I)

```

```

HT=AH(I)+BH(I)*TX+CH(I)*TX**2+DH(I)*TX**3

```

```

HP=HP+B(I,J)*HT

```

```

30 PCP=PCP+B(I,J)*PC(I)

```

```

PI=3.1415926536

```

```

PR=P/PCP

```

```

TR=T/TCP

```

```

23 GO TO (1,2,3,4),KENTH

```

```

1 WRITE(6,102)

```

```

GO TO 20

```

```

5 I=0

```

```

50 I=I+1

```

```

PCP=PC(I)

```

```

TCP=TC(I)

```

```

ZCP=ZC(I)

```

```

HP=AH(I)+BH(I)*TX+CH(I)*TX**2+DH(I)*TX**3

```

```

PR=P/PCP

```

```

TR=T/TCP

```

```

2 IF((PR.LT.0.01).OR.(PR.GT.1.0)) LIM=2

```

```

IF(ZCP.LT.0.28) GO TO 10

```

```

DHTC=5.4*(PR**0.6747)/(1.+1.227*((-ALOG(PR))**0.503))

```



```

GO TO 20
10 IF(ZCP.LT.0.26) GO TO 40
   DHTC=5.8*(PR**0.63163)/(1.+1.229*((-ALOG(PR))**0.55456))
   GO TO 20
40 IF(ZCP.LT.0.24) GO TO 41
   DHTC=6.5*(PR**0.62252)/(1.0+0.76218*((-ALOG(PR))**0.53042))
   GO TO 20
41 IF(ZCP.LT.0.22) GO TO 42
   DHTC=7.0*(PR**0.65135)/(1.0+0.75727*((-ALOG(PR))**0.46108))
   GO TO 20
42 WRITE(6,103) KENTH
   GO TO 20
   9 WRITE(6,100) PR,KENTH
   GO TO 21
   3 IF((PR.LT.0.01).OR.(PR.GT.1.0)) LIM=2
   DUMMY1=-ALOG(PR)
   IF(ZCP.LT.0.28) GO TO 12
   DHTC=(5.4+3.6485*(DUMMY1**0.33464))/(1.0-0.0056942*(-DUMMY1))
   GO TO 20
12 IF(ZCP.LT.0.26) GO TO 43
   DHTC=(5.8+5.19*(DUMMY1**0.4963))/(1.0-0.1*(-DUMMY1))
   GO TO 20
43 IF(ZCP.LT.0.24) GO TO 44
   DHTC=(6.5+4.48*(DUMMY1**0.3952))/(1.0-0.00185*(-DUMMY1))
   GO TO 20
44 IF(ZCP.LT.0.22) GO TO 42
   DHTC=(7.0+4.5688*(DUMMY1**0.333))/(1.0+0.004*(-DUMMY1))
   GO TO 20
   4 IF((PR.LT.0.01).OR.(PR.GT.30.)) LIM=2
   IF((TR.LT.0.5).OR.(TR.GT.1.0)) LIM=1
   DUMMY1=PR-4.2
   DUMMY2=TR-0.77
   DUMMY3=ALOG(PR)
   DUMMY4=ALOG(TR)
   IF(ZCP.LT.0.28) GO TO 15
   C1=-0.09572107*(DUMMY1)-9.501235*(DUMMY2)
   C2=-17.30389*((DUMMY2)**2)-0.3195707*(DUMMY1)*(DUMMY2)
   C3=1.368092*DUMMY3+4.227096*DUMMY3*DUMMY4
   C4=3.181639*DUMMY3*DUMMY4*DUMMY4+9.707447
   DHTC=C1+C2+C3+C4
   GO TO 20
15 IF(ZCP.LT.0.26) GO TO 45
   DUMMY1=PR-4.664
   DUMMY2=TR-0.79749
   C1=-0.1368774*DUMMY1-14.56975*DUMMY2
   C2=-7.812724*(DUMMY2**2)-0.1642482*DUMMY2*DUMMY1
   C3=1.036851*DUMMY3+4.463472*DUMMY3*DUMMY4
   C4=4.525831*DUMMY3*(DUMMY4**2)+10.86085
   DHTC=C1+C2+C3+C4
   GO TO 20
45 IF(ZCP.LT.0.24) GO TO 46
   C1=-0.1074635*DUMMY1-15.80132*DUMMY2

```



```

C2=-15.18611*(DUMMY2**2)-0.1476876*DUMMY1*DUMMY2
C3=0.7800774*DUMMY3+3.154058*DUMMY3*DUMMY4
C4=2.988533*DUMMY3*(DUMMY4**2)+12.28618
DHTC=C1+C2+C3+C4
GO TO 20
46 IF(ZCP.LT.0.22) GO TO 42
C1=-.08644293*DUMMY1-12.93889*DUMMY2
C2=10.81311*(DUMMY2**2)-0.1568094*DUMMY1*DUMMY2
C3=0.7466842*DUMMY3+3.17422*DUMMY3*DUMMY4
C4=2.930566*DUMMY3*(DUMMY4**2)+12.72429
DHTC=C1+C2+C3+C4
GO TO 20
7 WRITE(6,101) TR,KENTH
GO TO 21
20 ENTH=HP-(DHTC*TCP)
IF(LIM.EQ.2) GO TO 9
IF(LIM.EQ.1) GO TO 7
IF(KENTH.EQ.5) GO TO 51
22 RETURN
51 PH(I)=ENTH
IF(I.EQ.NCP) GO TO 22
GO TO 50
21 LIM=0
IF(KENTH.EQ.5) GO TO 51
GO TO 22
END

```


SUBROUTINE TRIAL(TF,HNT,N)

THIS SUBPROGRAM CALCULATES THE FEED TEMPERATURE FROM
THE FEED ENTHALPY BY TRIAL AND ERROR

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)

TT1=TF

KENTH=2

CALL ENTHAL(TT1,XT,KENTH,N)

QQ1=(ENTH*FR)-HNT

TT2=TT1

IF(QQ1.LT.0.) GO TO 70

72 TT2=TT2-50.

GO TO 71

70 TT2=TT2+50.

71 CALL ENTHAL(TT2,XT,KENTH,N)

QQ2=(ENTH*FR)-HNT

IF(ABS(QQ1-QQ2).GT.ABS(QQ1)) GO TO 73

IF(QQ1.LT.0.) GO TO 70

GO TO 72

73 IF(ABS(QQ2).GT.ABS(QQ1)) GO TO 74

GO TO 75

74 QQ=QQ1

TT=TT1

QQ1=QQ2

TT1=TT2

QQ2=QQ

TT2=TT

75 TT3=(TT1+TT2)/2.

KENTH=2

CALL ENTHAL(TT3,XT,KENTH,N)

QQ3=(ENTH*FR)-HNT

IF(ABS(QQ3).LT.HNT*0.0001) GO TO 76

WRITE(6,100) TT1,QQ1,TT2,QQ2,TT3,QQ3

100 FORMAT(6E16.8)

IF(ABS(QQ3-QQ1).GT.ABS(QQ1)) GO TO 79

IF(ABS(QQ2).GT.ABS(QQ3)) GO TO 81

QQ1=QQ3

TT1=TT3

GO TO 75

81 QQ1=QQ2

TT1=TT2

QQ2=QQ3


```
      TT2=TT3
      GO TO 75
79  IF (ABS(QQ3).GT.ABS(QQ1)) GO TO 80
      QQ2=QQ3
      TT2=TT3
      GO TO 75
80  QQ2=QQ1
      TT2=TT1
      TT1=TT3
      QQ1=QQ3
      GO TO 75
76  TF=TT3
      RETURN
      END
```


APPENDIX D
SUB-PROGRAMS FOR USE WITH
CHAO AND SEADER DATA

SUBROUTINE PHYS(CPNT)

CALCULATES PHYSICAL PROPERTIES FOR HYPOTHETICAL COMPONENTS
IN THE CHAO-SEADER CORRELATION BY CAVETT METHOD

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION CPNT(15,2)
REAL LO
50 FORMAT(1X,7F8.3,11X,2A6)
51 FORMAT(8F10.8)
M=NC+1
DO 20 I=M,NCP
  READ(5,50) BPCA,BMLA,BPMNA,TC1,PC1,API,XXWM,(CPNT(I,J)
  1,J=1,2)
  READ(5,51) ZM(I),LO(I)
  SPG=141.5/(API+131.5)
  IF(BPMNA.EQ.0.) GO TO 1
  GO TO 2
1 BPMNA=(BPCA+BMLA)/2.0
2 XRHO=0.98907*SPG
  V1(I)=XXWM/XRHO
  UOPK=((BPMNA+459.6)**(1.0/3.0))/SPG
  IF(TC1.EQ.0.) GO TO 3
  GO TO 4
3 IF(BMLA.EQ.0.) GO TO 9
  BP=BMLA
  GO TO 11
9 BP=BPMNA
11 CONTINUE
  TC1=768.07121+(1.7133693-0.10834003E-02*BP)*BP
  TC1=TC1-0.89212579E-02*API*BP+0.38890584E-06*BP**3
  TC1=TC1+((0.53094920E-05+0.327116E-07*API)*API)*BP**2
4 TC(I)=TC1
  IF(PC1.EQ.0.) GO TO 5
  GO TO 6
5 PC1=2.8290406+(.94120109E-03-.30474749E-05*BPMNA)*BPMNA
  PC1=PC1-0.20876110E-04*API*BPMNA+0.15184103E-08*BPMNA**3
  PC1=PC1+((+.11047899E-07+0.13949619E-09*API)*API)*BPMNA**2
  PC1=PC1-0.48271599E-07*API**2*BPMNA
  PC1=EXP(PC1*2.303)
6 PC(I)=PC1
  BP=BPMNA+459.6
  W(I)=(3./7.)*((ALOG(PC1/14.696))/2.303)/(TC1/BP-1.0)-1.0

```



```

DEHV= (7.58+4.571*(ALOG(BP    ))/2.303)*(BPMNA+459.6)/1.8
DEHV=DEHV*((TC1-537.)/(TC1-(BPMNA+459.6)))*0.38
DELTA(I) =((DEHV-592.4)/V1(I)    ) **0.5
CH(I)=XXWM*(3.1073165E-04-5.832381E-08*API)
DH(I)=XXWM*(9.1745019E-11*API-5.6334748E-08)
HB=-.81862040+    (-2.8568654E-05+1.7024654E-06*API)*API
HB=HB-1.4886832E-08*API**3    -3.0836492E-04*UOPK**3
HB=HB+(8.8395563E-02+4.2934703E-03*UOPK)*UOPK
BH(I)=XXWM*HB
HB=(3.5442502-(5.2716944E-02-3.5353777E-04*API)*API)*API
HB=HB-(8.9530784-3.5118581E-01*UOPK)*UOPK**2
HB=HB+(43.401618-5.9563889E-03*API)*UOPK+188.250
AH(I)=XXWM*HB
20 CONTINUE
RETURN
END

```


C
C
C

APPENDIX D ANNEX 2

SUBROUTINE KIDL(T)

```
C***** IDEAL K-RATIOS AS A FUNCTION OF TR AND PR ONLY
COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION FN1(20),AKK(20)
TX=T+459.6
DO 1 I=1,NCP
  J=1
  IF(I.EQ.JH2) GO TO 12
  IF(I.EQ.JC1) GO TO 11
  IF(I.EQ.JN2) GO TO 13
  IF(I.EQ.JCO) GO TO 11
  IF(I.EQ.JO2) GO TO 11
  IF(I.EQ.JCO2) GO TO 14
  IF(I.EQ.JH2S) GO TO 15
  GO TO 16
11 J=2
  GO TO 16
12 J=3
  GO TO 16
13 J=4
  GO TO 16
14 J=5
  GO TO 16
15 J=6
16 CONTINUE
  TR=TX/TC(I)
  PR=P/PC(I)
  FP1=(A(1,J)+A(2,J)/TR+A(3,J)*TR+A(4,J)*TR**2+A(5,J)*TR**3
1+(A(6,J)+A(7,J)*TR+A(8,J)*TR**2)*PR+(A(9,J)+A(10,J)*TR)
1*PR**2-ALOG(PR)/2.303
  FP2=(A(11,J)+A(12,J)*TR+A(13,J)/TR+A(14,J)*TR**3+A(15,J)
1*(PR-0.6))
  FN1(I)=(FP1+W(I)*FP2)*2.303
1 AKK(I)=EXP(FN1(I))
DO 99 I=1,NCP
99 EQ(I)=AKK(I)
RETURN
END
```



```

C
C
C
      SUBROUTINE K(T,KENTH,N)
C
C***** CHAO-SEADER K-RATIOS
C
      COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
      COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
      COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
      COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
      COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
      COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
      COMMON EQ(15)
      DIMENSION FNU(20),ARK(20),BRK(20),PHI(20),GAM(20),VAPL(20)
200  FORMAT(1X,40HMORE THAN THIRTY TRIALS ARE REQUIRED FOR,
114H Z CONVERGENCE)
      TX=T+459.6
      GO TO (1,1,2,2,3),KENTH
3   DO 101 I=1,NCP
      J=1
      IF(I.EQ.JH2) GO TO 12
      IF(I.EQ.JC1) GO TO 11
      IF(I.EQ.JN2) GO TO 13
      IF(I.EQ.JO2) GO TO 11
      IF(I.EQ.JCO) GO TO 11
      IF(I.EQ.JCO2) GO TO 14
      IF(I.EQ.JH2S) GO TO 15
      GO TO 16
11  J=2
      GO TO 16
12  J=3
      GO TO 16
13  J=4
      GO TO 16
14  J=5
      GO TO 16
15  J=6
16  CONTINUE
      TR=TX/TC(I)
      PR=P/PC(I)
      FPO=A(1,J)+A(2,J)/TR+A(3,J)*TR+A(4,J)*TR**2+A(5,J)*TR**3
1+(A(6,J)+A(7,J)*TR+A(8,J)*TR**2)*PR+(A(9,J)+A(10,J)*TR)
1*PR**2-ALOG(PR)/2.303
      FPI=(A(11,J)+A(12,J)*TR+A(13,J)/TR+A(14,J)*TR**3+A(15,J)
1*(PR-0.6))
101 FNU(I)=(FPO+W(I)*FPI)*2.303
      AMIX=0.
      BMIX=0.0
      DO 102 I=1,NCP
      TR=TX/TC(I)
      ARK(I)=(0.4278/(PC(I)*TR**2.5))**0.5

```



```

BRK(I)=0.0867/(PC(I)*TR)
BMIX=BMIX+BRK(I)*YT(I,N)
102 AMIX=AMIX+ARK(I)*YT(I,N)
AOB=AMIX*AMIX/BMIX
CON1=2.0
CON2=BMIX*P+0.001
DO 106 KK=1,30
ZAS=(CON1+CON2)/2.0
H=BMIX*P/ZAS
Z=1.0/(1.0-H)-AOB*(H/(1.0+H))
DEL=Z-ZAS
IF(ABS(DEL).LE.1.0E-04) GO TO 107
IF(DEL.LT.0.0) GO TO 104
IF(DEL.GT.0.) GO TO 105
104 CON1=ZAS
GO TO 106
105 CON2=ZAS
106 CONTINUE
WRITE(6,200)
107 AAOB(N)=AOB
BBMIX(N)=BMIX
ZC(N)=Z
IF(KENTH.LT.3) GO TO 4
DO 108 I=1,NCP
108 PHI(I)=(Z-1.0)*(BRK(I)/BMIX)-ALOG(Z-BMIX*P)-AOB*((2.0*
1ARK(I))/AMIX-(BRK(I)/BMIX))*ALOG(1.0+H)
2 CON1=0.
CON2=0.0
DO 109 I=1,NCP
DELMX=XT(I,N)*V1(I)
CON1=CON1+DELMX
109 CON2=CON2+DELMX*DELTA(I)
DELMX=CON2/CON1
DDELMX(N)=DELMX
IF(KENTH.LT.5) GO TO 4
CON1=1.987*TX/1.8
DO 110 I=1,NCP
GAM(I)=V1(I)*(DELTA(I)-DELMX)**2/CON1
VAPL(I)=(FNU(I)+GAM(I)-PHI(I))
110 EQ(I)=EXP(VAPL(I))
4 RETURN
END

```


SUBROUTINE BUBPT(T,B,N)

THIS SUBPROGRAM CALCULATES THE BUBBLE POINT FOR THE CHAO AND
SEADER DATA SET

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)

DIMENSION B(15,35)

100 FORMAT(1X,38HBUBPT MORE THAN THIRTY TRIALS REQUIRED)

105 FORMAT(1X,3HSY=,E15.8)

BPTV=.0001

TT=T

K1=1

CALL KIDL(TT)

DO 5 I=1,NCP

XT(I,N)=B(I,N)

YT(I,N)=EQ(I)*XT(I,N)

5 CONTINUE

KENTH=5

1 SY=0.

CALL K(TT,KENTH,N)

O=0.

DO 2 I=1,NCP

YY=XT(I,N)*EQ(I)

IF(ABS(YT(I,N)-YY).LT.BPTV) GO TO 4

O=1.

4 YT(I,N)=YY

2 SY=SY+YY

IF(ABS(SY-1.).GT.BPTV) GO TO 6

IF(O.LE.BPTV) GO TO 10

6 DO 3 I=1,NCP

3 YT(I,N)=YT(I,N)/SY

K1=K1+1

IF(K1.GT.30) GO TO 9

Q=TT*(1.0+(1.0-SY)/5.0)

IF(ABS(Q-TT).LT.30.) GO TO 8

IF((SY-1.0).GE.0.) GO TO 7

TT=TT+30.

GO TO 1

7 TT=TT-30.

GO TO 1

8 TT=Q

GO TO 1

9 WRITE(6,100)


```
WRITE(6,105) SY  
10 T=TT  
RETURN  
END
```


SUBROUTINE DEWPT(T,B,N)

THIS SUBPROGRAM CALCULATES THE DEWPOINT FOR THE CHAO AND
SEADER DATA SET

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION B(15,35)
100 FORMAT(1X,38HDEWPT MORE THAN THIRTY TRIALS REQUIRED)
105 FORMAT(1X,3HSX=,E15.8)
DPTV=.001
TT=T
K1=1
CALL KIDL(TT)
DO 5 I=1,NCP
YT(I,N)=B(I,N)
5 XT(I,N)=YT(I,N)/EQ(I)
KENTH=5
1 SX=0.
CALL K(TT,KENTH,N)
O=0.
DO 2 I=1,NCP
XX=YT(I,N)/EQ(I)
IF(ABS(XT(I,N)-XX).LT.DPTV) GO TO 4
O=1.
4 XT(I,N)=XX
2 SX=SX+XX
IF(ABS(SX-1.).GT.DPTV) GO TO 6
IF(O.LT.DPTV) GO TO 10
6 DO 3 I=1,NCP
3 XT(I,N)=XT(I,N)/SX
K1=K1+1
IF(K1.GT.30) GO TO 9
Q=TT*(1.0+(SX-1.0)/5.0)
IF(ABS(Q-TT).LT.30.) GO TO 8
IF((SX-1.0).GE.0.) GO TO 7
TT=TT-30.
GO TO 1
7 TT=TT+30.
GO TO 1
8 TT=Q
GO TO 1
9 WRITE(6,100)
WRITE(6,105) SX

```


10 T=TT
RETURN
END

SUBROUTINE FLASH (T,N)

THIS SUBPROGRAM CARRIES OUT FLASH CALCULATIONS FOR THE
CHAD AND SEADER DATA SET

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
KFL=0
Q=1.
GG=0.
VV=.001
3 GS1=0.
GS=0.
IF(KFL.LT.1) GO TO 5
CALL K(T,KENTH,N)
6 DO 1 I=1,NCP
  ZFI=ZF(I)
  GKF=1.-1./EQ(I)
  G=ZFI/(1.-Q*GKF)
  GS=GS+G
  G1=ZFI*GKF/((1.-Q*GKF)**2)
1 GS1=GS1+G1
  GS=GS-1.
  GG=GS
  Q=Q-GS/GS1
  KFL=1
  FL=Q*FR
  FV=FR-FL
  DO 4 I=1,NCP
    XF(I)=ZF(I)*FR/(FV*EQ(I)+FL)
    YF(I)=EQ(I)*XF(I)
    XM(I)=XF(I)*FL
    YM(I)=YF(I)*FV
    XT(I,N)=XF(I)
    YT(I,N)=YF(I)
4 CONTINUE
  IF(ABS(GS-GG).LT.VV) GO TO 2
  GO TO 3
5 CALL KIDL(T)
  GO TO 6
2 RETURN
END

```


SUBROUTINE ENTHAL(T,B,KENTH,N)

C***** CHAO-SEADER H-VALUES ARE CALCULATED

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION HIDL(20),YY(20),XX(20),HL(20),HAC(20),HFC(20)
DIMENSION B(15,35)
TX=T+459.6
DO 1 I=1,NCP
1 HIDL(I)=AH(I)+BH(I)*T+CH(I)*T**2+DH(I)*T**3
GO TO (5,5,2,2),KENTH
5 SUMHV=0.
DO 3 I=1,NCP
YT(I,N)=B(I,N)
3 SUMHV=SUMHV+YT(I,N)*HIDL(I)
CALL K(T,KENTH,N)
H=BBMIX(N)*P/ZC(N)
HVC=(1.5*AAOB(N)*ALOC(1.+H)+1.0-ZC(N))*1.987*TX
ENTH=SUMHV-HVC
GO TO 7
2 SUMHL=0.
DO 6 I=1,NCP
XT(I,N)=B(I,N)
6 CONTINUE
CALL K(T,KENTH,N)
DO 4 I=1,NCP
J=1
IF(I.EQ.JH2) GO TO 12
IF(I.EQ.JC1) GO TO 11
IF(I.EQ.JN2) GO TO 13
IF(J.EQ.JO2) GO TO 11
IF(I.EQ.JCO) GO TO 11
IF(I.EQ.JCO2) GO TO 14
IF(I.EQ.JH2S) GO TO 15
GO TO 16
11 J=2
GO TO 16
12 J=3
GO TO 16
13 J=4
GO TO 16
14 J=5
GO TO 16

```



```

15 J=6
16 CONTINUE
   TR=TX/TC(I)
   PR=P/PC(I)
   CON1=-A(2,J)/TR**2+A(3,J)+2.0*A(4,J)*TR+3.0*A(5,J)*TR
1**2+(A(7,J)+2.0*A(8,J)*TR)*PR+A(10,J)*PR**2+(A(12,J)-
1A(13,J)/TR**2+3.0*A(14,J)*TR**2)*W(I)
   CON1=CON1*2.30259/TC(I)
   HFC(I)=CON1
   HAC(I)=-((V1(I)*(DELTA(I)-DDELMX(N))**2)/(1.987*(TX**2
1)))*1.8
   HL(I)=- (HFC(I)+HAC(I))*1.987*TX**2+HIDL(I)
4 SUMHL=SUMHL+XT(I,N)*HL(I)
   ENTH=SUMHL
7 CONTINUE
   RETURN
   END

```


APPENDIX E
SUB-PROGRAMS FOR USE WITH
POLYNOMIAL DATA

C
C
C
SUBROUTINE K(T,KENTH,N)

C
C THIS SUBPROGRAM CALCULATES K RATIOS FROM POLYNOMIAL DATA
C

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH

COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)

COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)

COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)

COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA

COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)

COMMON EQ(15)

TT=T+459.6

DO 1 I=1,NCP

EQT=(A(I,1)+A(I,2)*TT+A(I,3)*(TT**2)+A(I,4)*(TT**3))**3

1 EQ(I)=EQT*TT

RETURN

END

SUBROUTINE BUBPT(T,B,N)

THIS SUBPROGRAM CALCULATES THE BUBBLE POINT FOR THE
POLYNOMIAL DATA SET

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)

DIMENSION B(15,35)

BPTV=.001

KT=1

TT=T

1 SY=0.

KENTH=0

CALL K(TT,KENTH,N)

DO 2 I=1,NCP

XT(I,N)=B(I,N)

2 SY=SY+XT(I,N)*EQ(I)

SQ=1.0-SY

IF(ABS(SQ).LT.BPTV) GO TO 4

KT=KT-1

IF(KT.LT.0) GO TO 3

SYO=SY

TO =TT

TT=TT-400.

GO TO 1

3 SLOPE=(SY-SYO)/(TT-TO)

TO=TT

TT=(SQ/SLOPE)+TT

SYO=SY

GO TO 1

4 T=TT

RETURN

END

C
C
C
SUBROUTINE ENTHAL(T,B,KH,J)

C THIS SUBPROGRAM CALCULATES ENTHALPIES FROM POLYNOMIAL DATA
C

```

COMMON NC,NHC,NCP,P,FR,FL,FV,XF(15),YF(15),ZF(15),ENTH
COMMON XM(15),YM(15),ZM(15),LO(15),X(15,35),Y(15,35)
COMMON XT(15,35),YT(15,35),BBMIX(35),AAOB(35),ZC(35)
COMMON AH(15),BH(15),CH(15),DH(15),EH(15),FH(15)
COMMON JH2,JC1,JN2,JO2,JCO,JCO2,JH2S,DDELMX(35),KDATA
COMMON TC(15),PC(15),W(15),DELTA(15),V1(15),A(16,6)
COMMON EQ(15)
DIMENSION B(15,35)
ENTH=0.
TT=T+459.6
GO TO(1,1,2,2),KH
2 DO 3 I=1,NCP
  H=(AH(I)+BH(I)*TT+CH(I)*(TT**2))**2
3 ENTH=ENTH+H*B(I,J)
  RETURN
1 DO 4 I=1,NCP
  H=(DH(I)+EH(I)*TT+FH(I)*(TT**2))**2
4 ENTH=ENTH+H*B(I,J)
  RETURN
END
```


APPENDIX F
PROBLEM STATEMENTS AND RESULTS
FOR EXAMPLE PROBLEMS

PROBLEM NO. 1
PROBLEM STATEMENT

ABSORBER
BUBBLE POINT METHOD

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

300.0

8

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0850

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	NOT SPECIFIED	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

	FEED		ABSORBER OIL	
COMPONENTS	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	70.000	0.7000	0.000	0.0000
ETHANE	15.000	0.1500	0.000	0.0000
PROPANE	10.000	0.1000	0.000	0.0000
N-BUTANE	4.000	0.0400	0.000	0.0000
N-PENTANE	1.000	0.0100	0.000	0.0000
N-OCTANE	0.000	0.0000	20.000	1.0000

SPECIFIED TOP PRODUCT RATE = 85.000 LB MOLES/U.T.

C. ENTHALPY DATA

YEN AND ALEXANDER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

NGAA POLYNOMIAL DATA AT CONVERGENCE PRESSURE = 3000. PSIA

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	85.00	25.00
2	100.00	90.00	25.00
3	100.00	90.00	25.00
4	100.00	90.00	25.00
5	100.00	90.00	25.00
6	100.00	90.00	25.00
7	100.00	90.00	30.00
8	100.00	95.00	35.00

PROBLEM NO. 1
BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	67.671	2.329
ETHANE	12.615	2.385
PROPANE	4.663	5.337
N-BUTANE	0.007	3.993
N-PENTANE	0.000	1.000
N-OCTANE	0.048	19.952
TOTAL RATES	85.004	34.996

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	35.25	85.00	34.42
2	61.64	99.42	37.27
3	72.24	102.27	38.21
4	78.17	103.21	38.32
5	83.58	103.32	37.97
6	90.71	102.97	37.34
7	100.94	102.34	36.60
8	114.92	101.60	35.00

CALCULATED FEED TEMPERATURE = 133.9

THETA = 1.000836

NUMBER OF ITERATIONS = 18

PROBLEM NO. 1
PROBLEM STATEMENT
BUBBLE POINT METHOD

ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

300.0

8

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0850

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

TEMPERATURE (DEG F)

CONDITION

FEED

NOT SPECIFIED

SATURATED VAPOUR

ABSORBER OIL

90.0

SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	70.000	0.7000	0.000	0.0000
ETHANE	15.000	0.1500	0.000	0.0000
PROPANE	10.000	0.1000	0.000	0.0000
N-BUTANE	4.000	0.0400	0.000	0.0000
N-PENTANE	1.000	0.0100	0.000	0.0000
N-OCTANE	0.000	0.0000	20.000	1.0000

SPECIFIED TOP PRODUCT RATE = 85.000 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	85.00	25.00
2	100.00	90.00	25.00
3	100.00	90.00	25.00
4	100.00	90.00	25.00
5	100.00	90.00	25.00
6	100.00	90.00	25.00
7	100.00	90.00	30.00
8	100.00	95.00	35.00

PROBLEM NO. 1
BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	67.132	2.868
ETHANE	12.257	2.743
PROPANE	4.996	5.004
N-BUTANE	0.211	3.789
N-PENTANE	0.000	1.000
N-OCTANE	0.406	19.594
TOTAL RATES	85.002	34.998

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	116.45	85.00	25.47
2	120.87	90.47	26.15
3	121.50	91.15	26.45
4	120.33	91.45	26.74
5	117.47	91.74	27.13
6	112.37	92.13	27.81
7	103.36	92.81	29.30
8	85.79	94.30	35.00

CALCULATED FEED TEMPERATURE = 38.3

THETA = 1.000169

NUMBER OF ITERATIONS = 16

PROBLEM NO. 1
PROBLEM STATEMENT
BUBBLE POINT METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

300.0

8

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0850

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

FEED	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	NOT SPECIFIED	SATURATED VAPOUR
	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	70.000	0.7000	0.000	0.0000
ETHANE	15.000	0.1500	0.000	0.0000
PROPANE	10.000	0.1000	0.000	0.0000
N-BUTANE	4.000	0.0400	0.000	0.0000
N-PENTANE	1.000	0.0100	0.000	0.0000
N-OCTANE	0.000	0.0000	20.000	1.0000

SPECIFIED TOP PRODUCT RATE = 85.000 LB MOLES/U.T.

C. ENTHALPY DATA

POLYNOMIAL DATA USED

D. EQUILIBRIUM RATIO DATA

POLYNOMIAL DATA USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	85.00	25.00
2	100.00	90.00	25.00
3	100.00	90.00	25.00
4	100.00	90.00	25.00
5	100.00	90.00	25.00
6	100.00	90.00	25.00
7	100.00	90.00	30.00
8	100.00	95.00	35.00

PROBLEM NO. 1
BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	67.951	2.049
ETHANE	12.284	2.716
PROPANE	4.509	5.491
N-BUTANE	0.083	3.917
N-PENTANE	0.000	1.000
N-OCTANE	0.173	19.827
TOTAL RATES	85.000	35.000

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	107.76	85.00	24.83
2	111.60	89.83	25.52
3	112.68	90.52	25.80
4	112.34	90.80	26.02
5	110.46	91.02	26.30
6	106.09	91.30	26.83
7	96.77	91.83	28.17
8	74.82	93.17	35.00

CALCULATED FEED TEMPERATURE = -7.0

THETA = 0.999923

NUMBER OF ITERATIONS = 34

PROBLEM NO. 1
PROBLEM STATEMENT
SUM RATES METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

300.0

NUMBER OF PLATES

8

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0850

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	38.0	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	70.000	0.7000	0.000	0.0000
ETHANE	15.000	0.1500	0.000	0.0000
PROPANE	10.000	0.1000	0.000	0.0000
N-BUTANE	4.000	0.0400	0.000	0.0000
N-PENTANE	1.000	0.0100	0.000	0.0000
OCTANE	0.000	0.0000	20.000	1.0000

SPECIFIED TOP PRODUCT RATE = 85.000 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	114.75	83.82	25.31
2	118.25	89.12	25.95
3	118.22	89.77	26.26
4	116.41	90.07	26.54
5	112.88	90.36	26.94
6	106.91	90.75	27.64
7	96.65	91.46	29.27
8	76.64	93.09	36.18

PROBLEM NO. 1
SUM RATES METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	67.107	2.893
ETHANE	12.239	2.761
PROPANE	4.975	5.025
N-BUTANE	0.209	3.791
N-PENTANE	0.000	1.000
OCTANE	0.411	19.589
TOTAL RATES	84.942	35.058

PLATE VARIABLES			
PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	117.16	84.94	25.52
2	121.59	90.46	26.21
3	122.21	91.15	26.53
4	120.97	91.47	26.81
5	118.06	91.75	27.20
6	112.88	92.14	27.86
7	103.83	92.80	29.35
8	86.18	94.30	35.06

NUMBER OF ITERATIONS = 8

PROBLEM NO. 1
PROBLEM STATEMENT

SUM-RATES METHOD

ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

300.0

8

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0850

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	-8.2	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	70.000	0.7000	0.000	0.0000
ETHANE	15.000	0.1500	0.000	0.0000
PROPANE	10.000	0.1000	0.000	0.0000
N-BUTANE	4.000	0.0400	0.000	0.0000
N-PENTANE	1.000	0.0100	0.000	0.0000
N-OCTANE	0.000	0.0000	20.000	1.0000

SPECIFIED TOP PRODUCT RATE = 85.000 LB MOLES/U.T.

C. ENTHALPY DATA

POLYNOMIAL DATA USED

D. EQUILIBRIUM RATIO DATA

POLYNOMIAL DATA USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		LIQUID RATE (LB MOLES) (PER U.T.)
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	
1	100.00	85.00	25.00
2	100.00	90.00	25.00
3	100.00	90.00	25.00
4	100.00	90.00	25.00
5	100.00	90.00	25.00
6	100.00	90.00	25.00
7	100.00	90.00	30.00
8	100.00	95.00	35.00

PROBLEM NO. 1
SUM RATES METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	67.950	2.050
ETHANE	12.282	2.718
PROPANE	4.508	5.492
N-BUTANE	0.084	3.916
N-PENTANE	0.000	1.000
N-OCTANE	0.175	19.825
TOTAL RATES	84.998	35.002

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	108.14	85.00	24.81
2	111.93	89.81	25.50
3	112.97	90.50	25.78
4	112.60	90.78	25.99
5	110.67	90.99	26.28
6	106.24	91.27	26.80
7	96.83	91.80	28.15
8	74.70	93.15	35.00

NUMBER OF ITERATIONS = 7

PROBLEM NO. 2
 PROBLEM STATEMENT
 BUBBLE POINT METHOD
 ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

60.0

4

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

FEED	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	NOT SPECIFIED	SATURATED VAPOUR
	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	57.80	128.80
2	110.00	76.10	135.10
3	120.00	82.60	140.90
4	135.00	85.80	152.60

PROBLEM NO. 2
BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.425	1.075
ETHANE	13.382	2.418
PROPANE	12.772	11.228
N-BUTANE	2.452	16.658
N-PENTANE	0.995	19.325
OCTANE	0.764	101.906
TOTAL RATES	57.790	152.610

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	112.34	57.80	126.49
2	121.90	73.99	132.05
3	128.38	79.35	136.71
4	125.26	84.10	152.60

CALCULATED FEED TEMPERATURE = 33.3

THETA = 0.999548

NUMBER OF ITERATIONS = 12

PROBLEM NO. 2
PROBLEM STATEMENT

BUBBLE POINT METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

60.0

4

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

FEED	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	NOT SPECIFIED 90.0	SATURATED VAPOUR SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
N-OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

YEN AND ALEXANDER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

NGAA POLYNOMIAL DATA AT CONVERGENCE PRESSURE = 3000. PSIA

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	57.80	130.00
2	110.00	75.00	135.00
3	120.00	85.00	140.00
4	135.00	90.00	152.60

PROBLEM NO. 2
BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.681	0.819
ETHANE	14.094	1.706
PROPANE	14.470	9.530
N-BUTANE	1.172	17.938
N-PENTANE	0.267	20.053
N-OCTANE	0.122	102.548
TOTAL RATES	57.806	152.594

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	50.92	57.80	150.69
2	82.56	98.09	164.55
3	110.99	111.95	171.50
4	153.08	118.90	152.60

CALCULATED FEED TEMPERATURE = 356.1

THETA = 1.000970

NUMBER OF ITERATIONS = 21

PROBLEM NO. 2
PROBLEM STATEMENT

ABSORBER
SUM RATES METHOD

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

60.0

4

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	29.5	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

	FEED		ABSORBER OIL	
COMPONENTS	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	57.80	128.80
2	110.00	76.10	135.10
3	120.00	82.60	140.90
4	135.00	85.80	152.30

PROBLEM NO. 2
SUM RATES METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.424	1.076
ETHANE	13.376	2.424
PROPANE	12.761	11.239
N-BUTANE	2.461	16.649
N-PENTANE	1.002	19.318
OCTANE	0.773	101.897
TOTAL RATES	57.797	152.603

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	112.83	57.80	126.63
2	122.30	74.03	132.05
3	128.52	79.44	136.70
4	124.82	84.10	152.60

NUMBER OF ITERATIONS = 9

PROBLEM NO. 3A
 PROBLEM STATEMENT
 BUBBLE POINT METHOD
 ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

91.5

7

INTER COOLER ON PLATE 3 WITH DUTY OF 1465000. BTU/U.T.

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.6800

TEMPERATURE WEIGHTING FACTOR = 0.100

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	NOT SPECIFIED	SATURATED VAPOUR
ABSORBER OIL	55.5	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
H2S	39.700	0.0369	0.000	0.0000
METHANE	482.500	0.4488	0.000	0.0000
ETHYLENE	45.500	0.0423	0.000	0.0000
ETHANE	226.800	0.2109	0.000	0.0000
PROPYLENE	70.100	0.0652	0.000	0.0000
PROPANE	115.300	0.1072	0.000	0.0000
1 BUTENE	31.400	0.0292	0.000	0.0000
N-BUTANE	37.500	0.0349	0.000	0.0000
N-PENTANE	26.400	0.0246	0.000	0.0000
ABSORBER OIL	0.000	0.0000	846.700	1.0000

SPECIFIED TOP PRODUCT RATE = 680.000 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	62.00	680.00	925.00
2	60.50	760.00	940.00
3	37.50	775.00	980.00
4	40.00	815.00	1000.00
5	42.00	835.00	1015.00
6	42.00	850.00	1040.00
7	21.40	870.00	1241.90

PROBLEM NO. 3 A

BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
H2S	14.138	25.562
METHANE	457.919	24.581
ETHYLENE	35.049	10.451
ETHANE	152.973	73.827
PROPYLENE	9.630	60.470
PROPANE	10.158	105.142
1 BUTENE	0.002	31.398
N-BUTANE	0.001	37.499
N-PENTANE	0.000	26.400
ABSORBER OIL	0.007	846.693
TOTAL RATES	679.878	1242.022

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	61.97	680.00	926.14
2	60.53	759.44	941.64
3	37.20	774.94	978.90
4	39.89	812.20	997.29
5	41.97	830.59	1013.58
6	41.94	846.88	1037.89
7	21.49	871.19	1241.90

THETA = 0.999310

NUMBER OF ITERATIONS = 15

PROBLEM NO. 3 A

COMPONENTS	MOLE PERCENT	ABSORBED
H ₂ S		64.39
METHANE		5.09
ETHYLENE		22.97
ETHANE		32.55
PROPYLENE		86.26
PROPANE		91.19
1 BUTENE		99.99
N-BUTANE		100.00
N-PENTANE		100.00
ABSORBER OIL		-0.00

PROBLEM NO. 3 B
PROBLEM STATEMENT
BUBBLE POINT METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

91.5

7

INTER COOLER ON PLATE 3 WITH DUTY OF 1000000. BTU/U.T.

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.6800

TEMPERATURE WEIGHTING FACTOR = 0.100

B. FEED DATA

TEMPERATURE (DEG F)

CONDITION

FEED

NOT SPECIFIED

SATURATED VAPOUR

ABSORBER OIL

55.5

SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES	MOLE	LB MOLES	MOLE
	PER U.T.	FRACTION	PER U.T.	FRACTION
H ₂ S	39.700	0.0369	0.000	0.0000
METHANE	482.500	0.4488	0.000	0.0000
ETHYLENE	45.500	0.0423	0.000	0.0000
ETHANE	226.800	0.2109	0.000	0.0000
PROPYLENE	70.100	0.0652	0.000	0.0000
PROPANE	115.300	0.1072	0.000	0.0000
1 BUTENE	31.400	0.0292	0.000	0.0000
N-BUTANE	37.500	0.0349	0.000	0.0000
N-PENTANE	26.400	0.0246	0.000	0.0000
ABSORBER OIL	0.000	0.0000	846.700	1.0000

SPECIFIED TOP PRODUCT RATE = 680.000 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	62.00	680.00	925.00
2	60.50	760.00	940.00
3	37.50	775.00	980.00
4	40.00	815.00	1000.00
5	42.00	835.00	1015.00
6	42.00	850.00	1040.00
7	21.40	870.00	1241.90

PROBLEM NO. 3
BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
H2S	14.335	25.365
METHANE	457.075	25.425
ETHYLENE	34.707	10.793
ETHANE	151.149	75.651
PROPYLENE	10.815	59.285
PROPANE	12.014	103.286
1 BUTENE	0.004	31.396
N-BUTANE	0.002	37.498
N-PENTANE	0.000	26.400
ABSORBER OIL	0.007	846.693
TOTAL RATES	680.106	1241.794

PLATE VARIABLES			
PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	62.39	680.00	927.94
2	62.18	761.24	944.71
3	46.95	778.01	974.94
4	48.81	808.24	988.66
5	49.83	821.96	998.46
6	47.85	831.76	1017.65
7	18.33	850.95	1241.90

THETA = 1.000246

NUMBER OF ITERATIONS = 37

PROBLEM NO. 3

COMPONENTS	MOLE PERCENT	ABSORBED
H ₂ S		63.89
METHANE		5.27
ETHYLENE		23.72
ETHANE		33.36
PROPYLENE		84.57
PROPANE		89.58
1 BUTENE		99.99
N-BUTANE		99.99
N-PENTANE		100.00
ABSORBER OIL		-0.00

PROBLEM NO. 4
 PROBLEM STATEMENT
 BUBBLE POINT METHOD

ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

91.5

7

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.7690

TEMPERATURE WEIGHTING FACTOR = 0.100

B. FEED DATA

FEED	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	NOT SPECIFIED	SATURATED VAPOUR
	56.4	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
H2S	38.000	0.0362	0.000	0.0000
METHANE	411.600	0.3924	0.000	0.0000
ETHYLENE	44.400	0.0423	0.000	0.0000
ETHANE	246.500	0.2350	0.000	0.0000
PROPYLENE	70.500	0.0672	0.000	0.0000
PROPANE	128.000	0.1220	0.000	0.0000
1 BUTENE	37.600	0.0358	0.000	0.0000
N-BUTANE	42.500	0.0405	0.000	0.0000
N-PENTANE	29.900	0.0285	0.000	0.0000
ABSORBER OIL	0.000	0.0000	838.000	1.0000

SPECIFIED TOP PRODUCT RATE = 769.000 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	70.00	769.00	850.00
2	70.00	750.00	850.00
3	70.00	800.00	850.00
4	70.00	850.00	850.00
5	70.00	900.00	850.00
6	70.00	1000.00	850.00
7	70.00	1075.00	1118.00

PROBLEM NO. 4
BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
H2S	26.728	11.272
METHANE	398.319	13.281
ETHYLENE	39.490	4.910
ETHANE	208.218	38.282
PROPYLENE	36.994	33.506
PROPANE	58.781	69.219
1 BUTENE	0.261	37.339
N-BUTANE	0.156	42.344
N-PENTANE	0.000	29.900
ABSORBER OIL	0.011	837.989
TOTAL RATES	768.958	1118.042

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	71.06	769.00	977.97
2	75.08	908.97	1008.79
3	77.13	939.79	1022.21
4	78.91	953.21	1031.46
5	81.40	962.46	1042.99
6	85.36	973.99	1063.05
7	89.62	994.05	1118.00

CALCULATED FEED TEMPERATURE = 68.2

THETA = 0.999108

NUMBER OF ITERATIONS = 20

PROBLEM NO. 4

COMPONENTS	MOLE PERCENT	ABSORBED
H ₂ S		29.66
METHANE		3.23
ETHYLENE		11.06
ETHANE		15.53
PROPYLENE		47.53
PROPANE		54.08
1 BUTENE		99.31
N-BUTANE		99.63
N-PENTANE		100.00
ABSORBER OIL		-0.00

PROBLEM NO. 5
PROBLEM STATEMENT

BUBBLE POINT METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

1200.0

6

INTER COOLER ON PLATE 3 WITH DUTY OF 236344. BTU/U.T.

THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 2.4970

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	NOT SPECIFIED	SATURATED VAPOUR
ABSORBER OIL	20.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
NITROGEN	40.850	0.0133	0.580	0.0012
CO2	11.600	0.0038	2.440	0.0049
H2S	3.410	0.0011	0.000	0.0000
METHANE	2377.610	0.7737	102.540	0.2058
ETHANE	461.420	0.1502	118.610	0.2380
PROPANE	147.730	0.0481	21.080	0.0423
I-BUTANE	7.260	0.0024	0.020	0.0000
N-BUTANE	19.040	0.0062	0.020	0.0000
I-PENTANE	1.730	0.0006	0.020	0.0000
N-PENTANE	1.640	0.0005	0.020	0.0000
N-HEXANE	0.600	0.0002	0.000	0.0000
N-OCTANE	0.000	0.0000	253.000	0.5077

SPECIFIED TOP PRODUCT RATE = 2497.590 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		LIQUID RATE (LB MOLES) (PER U.T.)
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	
1	40.00	2497.59	500.00
2	38.00	2650.00	700.00
3	36.00	2800.00	900.00
4	34.00	2950.00	1000.00
5	32.00	300.00	1150.00
6	30.00	3100.00	1073.63

PROBLEM NO. 5
BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
NITROGEN	38.480	2.950
CO2	8.712	5.328
H2S	0.801	2.609
METHANE	2087.429	392.721
ETHANE	329.695	250.335
PROPANE	30.408	138.402
I-BUTANE	0.060	7.220
N-BUTANE	0.036	19.024
I-PENTANE	0.004	1.746
N-PENTANE	0.003	1.657
N-HEXANE	0.000	0.600
N-OCTANE	3.202	249.798
TOTAL RATES	2498.829	1072.390

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	34.80	2497.59	672.19
2	34.11	2671.45	702.88
3	32.37	2702.14	753.69
4	35.03	2752.95	794.76
5	34.46	2794.02	873.98
6	31.31	2873.24	1073.63

CALCULATED FEED TEMPERATURE = 24.9

THETA = 1.002525

NUMBER OF ITERATIONS = 46

PROBLEM NO. 5
PROBLEM STATEMENT

SUM RATES METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

NUMBER OF PLATES

1200.0

6

INTER COOLER ON PLATE 3 WITH DUTY OF -236344. BTU/U.T.

PRODUCT STREAM CONVERGENCE TOLERANCE = 2.4976

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

TEMPERATURE (DEG F)

CONDITION

FEED

24.2

SATURATED VAPOUR

ABSORBER OIL

20.0

SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
NITROGEN	40.850	0.0133	0.580	0.0012
CO2	11.600	0.0038	2.440	0.0049
H2S	3.410	0.0011	0.000	0.0000
METHANE	2377.610	0.7737	102.540	0.2058
ETHANE	461.420	0.1502	118.610	0.2380
PROPANE	147.730	0.0481	21.080	0.0423
I-BUTANE	7.260	0.0024	0.020	0.0000
N-BUTANE	19.040	0.0062	0.020	0.0000
I-PENTANE	1.730	0.0006	0.020	0.0000
N-PENTANE	1.640	0.0005	0.020	0.0000
N-HEXANE	0.600	0.0002	0.000	0.0000
N-OCTANE	0.000	0.0000	253.000	0.5077

SPECIFIED TOP PRODUCT RATE = 2497.590 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		LIQUID RATE (LB MOLES) (PER U.T.)
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	
1	20.00	2500.00	500.00
2	20.00	2550.00	500.00
3	20.00	2600.00	500.00
4	20.00	2700.00	550.00
5	20.00	2800.00	600.00
6	20.00	2900.00	600.00

PROBLEM NO. 5
SUM RATES METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
NITROGEN	38.478	2.952
CO2	8.703	5.337
H2S	0.795	2.615
METHANE	2087.057	393.093
ETHANE	329.557	250.473
PROPANE	30.262	138.548
I-BUTANE	0.060	7.220
N-BUTANE	0.035	19.025
I-PENTANE	0.004	1.746
N-PENTANE	0.003	1.657
N-HEXANE	0.000	0.600
N-OCTANE	3.183	249.817
TOTAL RATES	2498.138	1073.082

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	34.67	2498.14	675.32
2	33.52	2675.13	708.35
3	31.54	2708.16	757.41
4	34.25	2757.21	794.43
5	33.93	2794.24	871.36
6	31.01	2871.17	1073.08

NUMBER OF ITERATIONS = 15

PROBLEM NO. 6
PROBLEM STATEMENT

BUBBLE POINT METHOD
REBOILED ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)	NO. OF PLATES (INCLUDING REBOILER)	FEED ENTERS ON PLATE NO.	SIDE STREAM TAKEN FROM PLATE NO.
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300.0	10	6	9
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SPECIFIED TOP PRODUCT RATE	SPECIFIED SIDE STREAM RATE
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95.000 LB MOLES/U.T.	15.000 LB MOLES/U.T.
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THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0950

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

FEED NUMBER 1	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	44.5	SATURATED VAPOUR
	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	80.000	0.8000	0.000	0.0000
ETHANE	6.667	0.0667	0.000	0.0000
PROPANE	6.667	0.0667	0.000	0.0000
N-BUTANE	6.667	0.0667	0.000	0.0000
OCTANE	0.000	0.0000	30.000	1.0000

C. ENTHALPY DATA

YEN AND ALEXANDER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

NGAA POLYNOMIAL DATA AT CONVERGENCE PRESSURE = 3000. PSIA

E. INITIAL ASSUMPTIONS

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	95.00	40.00
2	150.00	105.00	40.00
3	150.00	105.00	45.00
4	160.00	110.00	50.00
5	150.00	115.00	110.00
6	220.00	75.00	85.00
7	280.00	50.00	90.00
8	350.00	50.00	90.00
9	400.00	50.00	100.00
10	480.00	65.00	20.00

PROBLEM NO. 6

BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	TOP PRODUCT (LB MOLES) (PER U.T.)	BOTTOM PRODUCT (LB MOLES) (PER U.T.)	SIDE STREAM (LB MOLES) (PER U.T.)
METHANE	80.000	0.000	0.000
ETHANE	6.665	0.000	0.002
PROPANE	6.565	0.025	0.076
N-BUTANE	1.654	1.678	3.335
OCTANE	0.113	18.305	11.582
TOTAL RATES	94.997	20.009	14.994

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	64.41	95.00	52.59
2	116.96	117.59	61.35
3	143.13	126.35	66.60
4	156.89	131.60	70.43
5	162.05	135.43	76.43
6	259.70	41.43	110.68
7	293.94	75.68	110.59
8	350.97	75.59	109.20
9	439.36	74.20	140.97
10	502.48	105.97	20.00

CALCULATED REBOILER LOAD = 0.93753679E 06 BTU/U.T.

THETA(1) = 1.000000

THETA(2) = 1.000000

NUMBER OF ITERATIONS = 19

PROBLEM NO. 6
 PROBLEM STATEMENT
 BUBBLE POINT METHOD
 REBOILED ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)	NO. OF PLATES (INCLUDING REBOILER)	FEED ENTERS ON PLATE NO.	SIDE STREAM TAKEN FROM PLATE NO.
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300.0	10	6	9
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SPECIFIED TOP PRODUCT RATE	SPECIFIED SIDE STREAM RATE
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95.000 LB MOLES/U.T.	15.000 LB MOLES/U.T.
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THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0950

TEMPERATURE WEIGHTING FACTOR = 0.100

B. FEED DATA

FEED NUMBER 1	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	44.5	SATURATED VAPOUR
	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	80.000	0.8000	0.000	0.0000
ETHANE	6.667	0.0667	0.000	0.0000
PROPANE	6.667	0.0667	0.000	0.0000
N-BUTANE	6.667	0.0667	0.000	0.0000
N-OCTANE	0.000	0.0000	30.000	1.0000

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	100.00	95.00	40.00
2	150.00	105.00	40.00
3	150.00	105.00	45.00
4	160.00	110.00	50.00
5	150.00	115.00	110.00
6	220.00	75.00	85.00
7	280.00	50.00	90.00
8	350.00	50.00	90.00
9	400.00	50.00	100.00
10	480.00	65.00	20.00

PROBLEM NO. 6

BUBBLE POINT METHOD PRODUCT STREAMS

COMPONENTS	TOP PRODUCT (LB MOLES) (PER U.T.)	BOTTOM PRODUCT (LB MOLES) (PER U.T.)	SIDE STREAM (LB MOLES) (PER U.T.)
METHANE	79.999	0.000	0.001
ETHANE	6.664	0.000	0.002
PROPANE	6.400	0.078	0.188
N-BUTANE	1.399	1.974	3.293
N-OCTANE	0.538	17.949	11.513
TOTAL RATES	95.001	20.002	14.997

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	125.83	95.00	39.03
2	136.46	104.03	41.61
3	137.46	106.61	43.94
4	127.68	108.94	48.90
5	93.10	113.90	111.52
6	262.74	76.53	84.06
7	303.40	49.06	87.78
8	356.81	52.78	87.74
9	429.18	52.74	100.18
10	488.74	65.18	20.00

CALCULATED REBOILER LOAD = 0.89313927E 06 BTU/U.T.

THETA(1) = 0.999961

THETA(2) = 1.000280

NUMBER OF ITERATIONS = 36

PROBLEM NO. 7
PROBLEM STATEMENT

BUBBLE POINT METHOD
REBOILED ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)	NO. OF PLATES (INCLUDING REBOILER)	FEED ENTERS ON PLATE NO.	SIDE STREAM TAKEN FROM PLATE NO.
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285.0	16	6	(NO SIDE STREAM)
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SPECIFIED TOP PRODUCT RATE	SPECIFIED SIDE STREAM RATE
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677.000 LB MOLES/U.T.	0.000 LB MOLES/U.T.
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THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.6770

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED NUMBER 1	50.0	VAPOUR/LIQUID
ABSORBER OIL	-5.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	180.500	0.1055	0.000	0.0000
ETHANE	474.500	0.2773	0.000	0.0000
PROPANE	440.200	0.2573	0.000	0.0000
I-BUTANE	64.300	0.0376	0.000	0.0000
N-BUTANE	128.800	0.0753	0.000	0.0000
I-PENTANE	19.500	0.0114	0.000	0.0000
N-PENTANE	19.400	0.0113	0.000	0.0000
N-HEXANE	22.100	0.0129	0.500	0.0019
N-HEPTANE	5.300	0.0031	2.100	0.0079
N-NONANE	128.300	0.0750	95.300	0.3584
N-DECANE	228.000	0.1333	168.000	0.6318

C. ENTHALPY DATA

YEN AND ALEXANDER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

NGAA POLYNOMIAL DATA AT CONVERGENCE PRESSURE = 3000. PSIA

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	72.00	677.00	280.00
2	80.00	700.00	320.00
3	90.00	800.00	350.00
4	100.00	800.00	500.00
5	110.00	900.00	650.00
6	120.00	1000.00	900.00
7	130.00	800.00	1050.00
8	140.00	800.00	1100.00
9	150.00	800.00	1100.00
10	160.00	800.00	1100.00
11	170.00	800.00	1100.00
12	180.00	800.00	1200.00
13	193.00	800.00	1200.00
14	200.00	800.00	1300.00
15	210.00	800.00	1300.00
16	250.00	800.00	1299.80

PROBLEM NO. 7

BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	TOP PRODUCT (LB MOLES) (PER U.T.)	BOTTOM PRODUCT (LB MOLES) (PER U.T.)	SIDE STREAM (LB MOLES) (PER U.T.)
METHANE	180.500	0.000	0.000
ETHANE	465.126	9.374	0.000
PROPANE	31.102	409.098	0.000
I-BUTANE	0.072	64.228	0.000
N-BUTANE	0.025	128.775	0.000
I-PENTANE	0.000	19.500	0.000
N-PENTANE	0.000	19.400	0.000
N-HEXANE	0.006	22.594	0.000
N-HEPTANE	0.009	7.391	0.000
N-NONANE	0.063	223.537	0.000
N-DECANE	0.042	395.958	0.000
TOTAL RATES	676.946	1299.854	0.000

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	55.04	677.00	712.29
2	76.83	1123.39	709.96
3	88.20	1121.06	707.94
4	96.90	1119.04	706.16
5	104.70	1117.26	706.74
6	108.03	943.57	2250.62
7	120.45	950.82	2252.80
8	127.85	953.00	2252.60
9	136.15	952.80	2252.20
10	146.39	952.40	2252.63
11	157.76	952.83	2254.32
12	168.76	954.52	2256.85
13	178.33	957.05	2259.35
14	186.61	959.55	2260.31
15	196.96	960.51	2246.14
16	260.84	946.34	1299.80

CALCULATED REBOILER LOAD = 0.56045933E 07 BTU/U.T.

THETA(1) = 1.000000

THETA(2) = 1.000000

NUMBER OF ITERATIONS = 28

PROBLEM NO. 7
PROBLEM STATEMENT

BUBBLE POINT METHOD
REBOILED ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)	NO. OF PLATES (INCLUDING REBOILER)	FEED ENTERS ON PLATE NO.	SIDE STREAM TAKEN FROM PLATE NO.
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285.0	16	6	(NO SIDE STREAM)
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SPECIFIED TOP PRODUCT RATE	SPECIFIED SIDE STREAM RATE
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677.000 LB MOLES/U.T.	0.000 LB MOLES/U.T.
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THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.6770

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

FEED NUMBER 1	TEMPERATURE (DEG F)	CONDITION
ABSORBER OIL	50.0	VAPOUR/LIQUID
	-5.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	180.000	0.1052	0.000	0.0000
ETHANE	474.500	0.2774	0.000	0.0000
PROPANE	440.200	0.2574	0.000	0.0000
I-BUTANE	64.300	0.0376	0.000	0.0000
N-BUTANE	128.800	0.0753	0.000	0.0000
I-PENTANE	19.500	0.0114	0.000	0.0000
N-PENTANE	19.400	0.0113	0.000	0.0000
N-HEXANE	22.100	0.0129	0.500	0.0019
N-HEPTANE	5.300	0.0031	2.100	0.0079
N-NONANE	128.300	0.0750	95.300	0.3584
N-DECANE	228.000	0.1333	168.000	0.6318

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	70.00	677.00	300.00
2	80.00	750.00	350.00
3	90.00	850.00	400.00
4	100.00	950.00	500.00
5	110.00	1000.00	600.00
6	120.00	1100.00	700.00
7	130.00	1150.00	800.00
8	140.00	1200.00	900.00
9	150.00	1200.00	1000.00
10	160.00	1200.00	1000.00
11	170.00	1250.00	1000.00
12	180.00	1250.00	1000.00
13	190.00	1300.00	1000.00
14	200.00	1350.00	1000.00
15	210.00	1400.00	1100.00
16	260.00	1450.00	1299.30

PROBLEM NO. 7

BUBBLE POINT METHOD

PRODUCT STREAMS

COMPONENTS	TOP PRODUCT (LB MOLES) (PER U.T.)	BOTTOM PRODUCT (LB MOLES) (PER U.T.)	SIDE STREAM (LB MOLES) (PER U.T.)
METHANE	180.000	0.000	0.000
ETHANE	457.902	16.598	0.000
PROPANE	38.659	401.541	0.000
I-BUTANE	0.182	64.118	0.000
N-BUTANE	0.076	128.724	0.000
I-PENTANE	0.000	19.500	0.000
N-PENTANE	0.000	19.400	0.000
N-HEXANE	0.017	22.583	0.000
N-HEPTANE	0.027	7.373	0.000
N-NONANE	0.174	223.426	0.000
N-DECANE	0.129	395.871	0.000
TOTAL RATES	677.167	1299.133	0.000

PLATE VARIABLES

PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	79.59	677.00	492.43
2	89.94	903.53	511.74
3	94.87	922.84	521.10
4	96.88	932.20	536.08
5	93.04	947.18	595.07
6	81.52	974.72	2381.05
7	92.35	1081.75	2502.01
8	96.60	1202.71	2537.75
9	100.44	1238.45	2553.93
10	106.47	1254.63	2576.50
11	116.15	1277.20	2623.49
12	129.35	1324.19	2704.68
13	144.25	1405.38	2810.14
14	159.25	1510.84	2889.79
15	178.91	1590.49	2689.96
16	252.94	1390.66	1299.30

CALCULATED REBOILER LOAD = 0.15536768E 08 BTU/U.T.

THETA(1) = 1.003016

THETA(2) = 1.000000

NUMBER OF ITERATIONS = 25

PROBLEM NO. 7
PROBLEM STATEMENT

BUBBLE POINT METHOD
REBOILED ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)	NO. OF PLATES (INCLUDING REBOILER)	FEED ENTERS ON PLATE NO.	SIDE STREAM TAKEN FROM PLATE NO.
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270.0	16	6	(NO SIDE STREAM)
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SPECIFIED TOP PRODUCT RATE	SPECIFIED SIDE STREAM RATE
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677.000 LB MOLES/U.T.	0.000 LB MOLES/U.T.
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THETA CONVERGENCE TOLERANCE = 0.0010

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.6770

TEMPERATURE WEIGHTING FACTOR = 0.250

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED NUMBER 1	50.0	VAPOUR/LIQUID
ABSORBER OIL	-5.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
NITROGEN	0.700	0.0004	0.000	0.0000
CO2	12.400	0.0072	0.000	0.0000
METHANE	167.400	0.0978	0.000	0.0000
ETHANE	474.500	0.2773	0.000	0.0000
PROPANE	440.200	0.2573	0.000	0.0000
I-BUTANE	64.300	0.0376	0.000	0.0000
N-BUTANE	128.800	0.0753	0.000	0.0000
I-PENTANE	19.500	0.0114	0.000	0.0000
N-PENTANE	19.400	0.0113	0.000	0.0000
N-HEXANE	13.100	0.0077	0.000	0.0000
HYPH CPNT 1	9.000	0.0053	0.500	0.0019
HYPH CPNT 2	5.300	0.0031	2.100	0.0079
HYPH CPNT 3	128.300	0.0750	95.300	0.3584
HYPH CPNT 4	203.300	0.1188	149.900	0.5637
HYPH CPNT 5	24.700	0.0144	18.100	0.0681

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	75.00	677.00	270.00
2	90.00	750.00	350.00
3	100.00	800.00	430.00
4	110.00	850.00	500.00
5	120.00	900.00	580.00
6	135.00	950.00	660.00
7	150.00	900.00	740.00
8	160.00	900.00	820.00
9	175.00	900.00	900.00
10	190.00	900.00	980.00
11	200.00	950.00	1060.00
12	210.00	1000.00	1140.00
13	220.00	1000.00	1200.00
14	230.00	1000.00	1250.00
15	240.00	1000.00	1270.00
16	250.00	1000.00	1299.80

PROBLEM NO. 7

BUBBLE POINT METHOD
PRODUCT STREAMS

COMPONENTS	TOP PRODUCT (LB MOLES) (PER U.T.)	BOTTOM PRODUCT (LB MOLES) (PER U.T.)	SIDE STREAM (LB MOLES) (PER U.T.)
NITROGEN	0.700	0.000	0.000
CO2	12.398	0.002	0.000
METHANE	167.400	0.000	0.000
ETHANE	455.166	19.334	0.000
PROPANE	41.081	399.119	0.000
I-BUTANE	0.194	64.106	0.000
N-BUTANE	0.079	128.721	0.000
I-PENTANE	0.000	19.500	0.000
N-PENTANE	0.000	19.400	0.000
N-HEXANE	0.000	13.100	0.000
HYPH CPNT 1	0.007	9.493	0.000
HYPH CPNT 2	0.008	7.392	0.000
HYPH CPNT 3	0.097	223.503	0.000
HYPH CPNT 4	0.048	353.152	0.000
HYPH CPNT 5	0.002	42.798	0.000
TOTAL RATES	677.181	1299.619	0.000

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	74.07	677.00	469.84
2	83.84	880.94	487.25
3	88.37	898.35	496.12
4	89.87	907.22	511.17
5	85.08	922.27	574.30
6	76.44	943.97	2305.76
7	86.39	1005.96	2414.47
8	90.18	1114.67	2447.75
9	93.38	1147.95	2463.02
10	98.32	1163.22	2481.14
11	106.50	1181.34	2515.57
12	118.61	1215.77	2579.48
13	133.64	1279.69	2675.40
14	149.44	1375.60	2763.46
15	168.76	1463.66	2616.17
16	238.35	1316.37	1299.80

CALCULATED REBOILER LOAD = 0.14190452E 08 BTU/U.T.

THETA(1) = 1.003597

THETA(2) = 1.000000

NUMBER OF ITERATIONS = 29

PROBLEM NO. 2
PROBLEM STATEMENTSUM RATES METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

60.0

NUMBER OF PLATES

4

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	0.0	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		LIQUID RATE (LB MOLES) (PER U.T.)
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	
1	100.00	57.80	128.80
2	110.00	76.10	135.10
3	120.00	82.60	140.90
4	135.00	85.80	152.30

PROBLEM NO. 2

SUM RATES METHOD

PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.367	1.133
ETHANE	13.191	2.609
PROPANE	12.000	12.000
N-BUTANE	2.182	16.928
N-PENTANE	0.949	19.371
OCTANE	0.732	101.938
TOTAL RATES	56.421	153.979

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	111.45	56.42	125.92
2	120.20	71.94	131.07
3	125.60	77.09	135.61
4	119.37	81.63	153.98

NUMBER OF ITERATIONS = 9

PROBLEM NO. 2
PROBLEM STATEMENT

SUM RATES METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

60.0

NUMBER OF PLATES

4

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	20.0	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	111.45	56.42	125.92
2	120.20	71.94	131.07
3	125.60	77.09	135.61
4	119.37	81.63	153.98

PROBLEM NO. 2
SUM RATES METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.406	1.094
ETHANE	13.318	2.482
PROPANE	12.516	11.484
N-BUTANE	2.366	16.744
N-PENTANE	0.984	19.336
OCTANE	0.759	101.911
TOTAL RATES	57.348	153.052

PLATE VARIABLES			
PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	112.38	57.35	126.40
2	121.61	73.35	131.73
3	127.56	78.68	136.35
4	123.05	83.29	153.05

NUMBER OF ITERATIONS = 17

PROBLEM NO. 2
PROBLEM STATEMENT

SUM RATES METHOD
ABSORBER

A. COLUMN DATA

PRESSURE (PSIA)

60.0

NUMBER OF PLATES

4

PRODUCT STREAM CONVERGENCE TOLERANCE = 0.0578

TEMPERATURE WEIGHTING FACTOR = 1.000

B. FEED DATA

	TEMPERATURE (DEG F)	CONDITION
FEED	29.7	SATURATED VAPOUR
ABSORBER OIL	90.0	SUB-COOLED LIQUID

COMPONENTS	FEED		ABSORBER OIL	
	LB MOLES PER U.T.	MOLE FRACTION	LB MOLES PER U.T.	MOLE FRACTION
METHANE	28.500	0.2850	0.000	0.0000
ETHANE	15.800	0.1580	0.000	0.0000
PROPANE	24.000	0.2400	0.000	0.0000
N-BUTANE	16.900	0.1690	2.210	0.0200
N-PENTANE	14.800	0.1480	5.520	0.0500
OCTANE	0.000	0.0000	102.670	0.9300

SPECIFIED TOP PRODUCT RATE = 57.800 LB MOLES/U.T.

C. ENTHALPY DATA

CHAO-SEADER CORRELATION USED

D. EQUILIBRIUM RATIO DATA

CHAO-SEADER CORRELATION USED

E. INITIAL ASSUMPTIONS

PLATE NO.	PLATE VARIABLES		
	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	112.38	57.35	126.40
2	121.61	73.35	131.73
3	127.56	78.68	136.35
4	123.05	83.29	153.05

PROBLEM NO. 2
SUM RATES METHOD
PRODUCT STREAMS

COMPONENTS	DRY GAS (LB MOLES) (PER U.T.)	RICH OIL (LB MOLES) (PER U.T.)
METHANE	27.424	1.076
ETHANE	13.378	2.422
PROPANE	12.767	11.233
N-BUTANE	2.463	16.647
N-PENTANE	1.002	19.318
OCTANE	0.773	101.897
TOTAL RATES	57.808	152.592

PLATE VARIABLES			
PLATE NO.	TEMPERATURE (DEG F)	VAPOUR RATE (LB MOLES) (PER U.T.)	LIQUID RATE (LB MOLES) (PER U.T.)
1	112.85	57.81	126.64
2	122.32	74.05	132.06
3	128.55	79.47	136.71
4	124.87	84.12	152.59

NUMBER OF ITERATIONS = 24

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